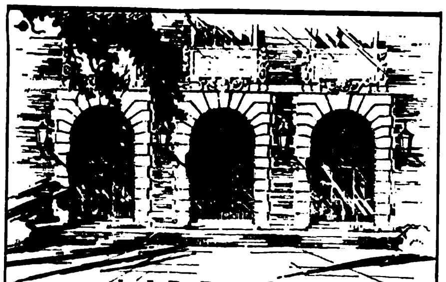


41st Congress, 2d Session. } HOUSE OF REPRESENTATIVES. { Ex. Doc. No. 206.

REPORT OF THE SUPERINTENDENT

OF THE

UNITED STATES COAST SURVEY,

SHOWING

THE PROGRESS OF THE SURVEY

DURING

THE YEAR 1869.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1872.

IN THE SENATE OF THE UNITED STATES,
June 23, 1870.

Resolved, (the House of Representatives concurring,) That there be printed of the Report of the Superintendent of the United States Coast Survey for the year 1869, one thousand extra copies for the use of the Senate, two thousand extra copies for the use of the House of Representatives, and one thousand extra copies for distribution by the Superintendent of the Coast Survey.

Attest:

GEORGE C. GORHAM,
Secretary.

IN THE HOUSE OF REPRESENTATIVES OF THE UNITED STATES,
July 6, 1870.

Resolved, That the House concur in the foregoing resolution of the Senate to print extra copies of the Report of the Superintendent of the United States Coast Survey, viz: one thousand for the use of the Senate, two thousand for the use of the House of Representatives, and one thousand for distribution by the Superintendent.

Attest:

EDW. McPHERSON,
Clerk.

LETTER

FROM

THE SECRETARY OF THE TREASURY

TRANSMITTING

THE ANNUAL REPORT OF THE SUPERINTENDENT OF THE U. S. COAST SURVEY FOR 1869.

TREASURY DEPARTMENT, *March* 17, 1870.

SIR: I have the honor to transmit, for the information of the House of Representatives, a report made to this Department by Professor Benjamin Peirce, Superintendent of the Coast Survey, stating the operations and progress in the survey of the coast during the year ending November 1, 1869, and the manuscript map of progress brought up to the same date, in accordance with the act of Congress approved March 3, 1853.

I have the honor to be, very respectfully,

GEO. S. BOUTWELL,
Secretary of the Treasury.

HON. JAMES G. BLAINE,
Speaker of the House of Representatives.

ABSTRACT OF CONTENTS OF REPORT.

CONTENTS OF APPENDIX.

ALPHABETICAL INDEX.

REPORT.

COAST SURVEY OFFICE,
Washington, D. C., December 20, 1869.

SIR: In accordance with law, I have the honor to submit a report on the progress made in the survey of the coasts of the United States during the year which ended with the month of November.

With but two exceptions the work has been continued in every seaboard State on the Atlantic coast, on the Gulf of Mexico, and on the Pacific coast, and special operations of interest and value have been conducted in some of the interior States. These will be alluded to in the brief recapitulation which will now be made of the sites of work. The progress of the parties severally has been satisfactory, and has not been interrupted, except in the case of a few parties on the coast of Maine, that suffered delay in consequence of the great storm of the 8th of September, which destroyed the camps. The regular operations of the survey have been continued on the shores of St. Croix River, Maine; in Penobscot Bay and the adjacent waters, and on Penobscot River; on Kennebec River; on the upper shores of Casco Bay; in the vicinity of Portland; and on the coast near Kennebunkport. The harbors between Mount Desert Island and Boston have been specially examined with reference to the compilation of a Coast Pilot; and local examinations have been made to determine questions concerning the light-house service in St. Croix River; in Prospect Harbor, Maine; and at Salem Harbor, Massachusetts. An astronomical party at Cambridge exchanged star signals with a party at Omaha, for determining difference of longitude by the telegraph. On this work, as a basis, the geographical positions of Springfield and Mattoon, in the State of Illinois; of Burlington and Des Moines, in Iowa; of Julesburg, North Platte, and Bushnell, in Nebraska; of Rawlings, in Wyoming Territory; Ann Arbor, in Michigan; and of Pittsburg, in Pennsylvania, have been actually determined.

Advantage was taken of the very favorable opportunity presented by the total eclipse of the sun on the 7th of August to make such precise observations as would be available for correcting the lunar elements. The party under my immediate direction observed at Springfield, Illinois; and three other parties of the Coast Survey made successful observations at Des Moines, Iowa; Shelbyville, Kentucky; and Bristol, Tennessee. The results will doubtless give to the determination of difference of longitude, by the method of occultations and eclipses, those data which were needed for its perfection. All observations made by the navigator for his position at sea will become more efficient by the improvements in the tables of the moon, which will arise from the correction of its elements.

Resuming the notice of work on the coast in geographical order, progress has been made in the detailed survey for a chart of Narraganset Bay; special examinations have been made of the channels near Sandy Hook; of those entering Wallabout Bay; and of New York Harbor; and the survey has been continued on the coast of New Jersey, near Atlantic City. A special examination has been made of the light-houses, beacons, and buoys in Chesapeake Bay, as a system of aids for navigation. Work has been continued in the survey of the lower estuaries of the Chesapeake; in the main triangulation near Washington City, and in that passing southward from Cape Henry, for which also a base line has been measured near Norfolk, Virginia; in soundings off the seacoast below Portsmouth, North Carolina; in Pamplico Sound and on the shores of its branches in the vicinity of Pamplico River; on the bar and channels of Charleston Entrance, South Carolina; on the coast of South Carolina between Port Royal and Savannah; on the coast of Georgia, at Wilmington River and Skiddaway Island; along the inland water passages below the Ogeechee; on Altamaha Sound and its branches; in the water passages between that sound and St. Simon's; on

the bar and in the channels leading to St. Andrew's Sound and to Fernandina Harbor, Florida; in the Gulf Stream off the Florida Peninsula; on the Gulf coast, at St Andrew's Bay and westward of Pensacola Entrance; on the islands and in the waters of Isle au Breton Sound, Louisiana; and in Corpus Christi Bay, Texas.

On the Pacific coast the survey has been prosecuted in four sites of work on the shores of the Santa Barbara Channel. The longitude of San Francisco has been determined by the telegraphic method, in connection with Salt Lake City and other points to the eastward. The series of stations used in this determination have been already mentioned. Work has been continued on the coast of California, near Cape Mendocino; on the coast of Oregon, near Port Orford; and on the Columbia River; and in Washington Territory, on the shore of the Strait of Fuca, at Port Discovery.

The solar eclipse of August last was observed by a party on the Chilkaht River, in Alaska, and some observations of value were obtained, though the weather was unfavorable. Taking the opportunity, the observing party determined a number of geographical positions before returning to San Francisco. Charts of all the principal harbors on the coast of Alaska have been compiled from the best information as yet available, and have been issued from the office. In other respects the drawing and engraving have kept pace with the progress of the field-work.

A comprehensive view of the distribution of the field parties upon the coast of the United States during the year is given in Appendix No. 1.

ESTIMATES.

The estimates for continuing the work of the survey during the fiscal year 1870–'71 were transmitted to the department at the end of September last. They will be stated here in detail, as usual, with the remarks then made in explanation of the several items.

The estimates for the Atlantic coast do not much exceed those of preceding years. Recent appropriations have been reductions from the estimates so large as seriously to embarrass the operations of the survey. The estimates have been carefully revised, with strict regard to economical considerations and the thorough efficiency of the service. They are offered with confidence that they will bear minute and rigid scrutiny. The necessity for the addition of $21,000 to the estimate of last year for the Atlantic coast arises from the increased outlay which is required to restore the field of operations in the southern sections to a proper working condition.

The augmentation of $100,000 in the estimates for the Pacific coast is small in comparison with its rapidly increasing development in wealth, population, and commerce, which demand a proportionate increase in all the facilities for navigation. It is especially incumbent upon the Coast Survey to make immediate provision for the supply of all the needful charts.

The item for the repairing of vessels is reduced by $15,000 from the estimates made for that object last year, in the expectation that some provision will already have been made for the supply of new vessels in the deficiency bill before the estimates now presented can receive the consideration of Congress. The item is, however, greater than the appropriation of last year, on account of the enhanced cost of repairs and the growing age of the vessels.

No estimate is here proposed for the extension of the survey to the coast of Alaska. If it should be thought proper by Congress to direct such an extension, an additional appropriation would be requisite.

Estimates in detail.

For general expenses of all the sections, namely: Rent, fuel, materials for drawing, engraving and printing, and for transportation of instruments, maps, and charts; for miscellaneous office expenses, and for the purchase of new instruments, books, maps, and charts.. $25,000

SECTION I. *Coast of Maine, New Hampshire, Massachusetts, and Rhode Island.* FIELD-WORK.—To continue the triangulation of the branches of *Passamaquoddy Bay*, and to extend the work so as to include the northeastern boundary along the *St. Croix River;* to continue the topography of the western shore of *Passamaquoddy Bay;* the upper estuaries of *Frenchman's Bay;* that of the islands and shores of *Penobscot*

Bay; that of *Saco Bay;* and of the shores and islands of *Narraganset Bay;* to continue off-shore soundings along the coast of *Maine;* and the hydrography of *Frenchman's Bay, Goldsborough Bay, Penobscot Bay,* and *Isle au Haut Bay;* to continue tidal and magnetic observations. OFFICE-WORK.—To make the computations from field observations; to continue the engraving of General Coast Chart No. I, (*Seal Island to Cape Cod;*) to continue the drawing and engraving of Coast Chart No. 4, (*Naskeag Point to White Head light, including Penobscot Bay;*) that of No. 6, (*Kennebec Entrance to Wood Island light;*) that of No. 7, (*Seguin light to Cape Porpoise light;*) that of No. 10, (*Cape Cod Bay;*) and of coast chart No. 13, (*from Cuttyhunk to Point Judith, including Narraganset Bay;*) and to continue the drawing and engraving of the harbor and river charts of the coast of *Maine* and of *Narraganset Bay,* will require $80, 000

SECTION II. *Coast of Connecticut, New York, New Jersey, Pennsylvania, and part of Delaware.* FIELD-WORK.—To make supplementary astronomical observations; to continue the topography of the shores of the *Hudson River;* to execute such supplementary hydrography as may be required in *New York Bay* and *Delaware Bay;* to continue the tidal observations. OFFICE-WORK.—To make the computations and reductions; to continue the drawing and engraving of a chart of *New York Harbor* on a large scale; to complete Coast Chart No. 21, (*from Sandy Hook to Barnegat;*) and to continue No. 22, (*from Barnegat Bay to Absecom Inlet,*) will require 15, 000

SECTION III. *Coast of part of Delaware, and that of Maryland, and part of Virginia.* FIELD-WORK.—To continue astronomical and magnetic observations in this section; to continue the primary triangulation parallel to the coast, southward along the *Blue Ridge;* to continue the topography of the sea-coast north of *Cape Charles,* and of the shores of *James River,* and triangulation requisite therefor; to complete the hydrographic survey of *James River,* and of estuaries and inlets remaining unsurveyed in this section; to continue tidal and magnetic observations. OFFICE-WORK.—To make the computations from field-work; to continue the drawing and engraving of Coast Charts No. 29 and No. 30, (*from Chincoteague Inlet to Cape Henry;*) and of General Coast Chart No. IV, (*approaches to Delaware and Chesapeake Bay;*) and to commence a chart of the lower part of *James River,* and engrave supplementary work on the charts heretofore published, will require 38, 000

SECTION IV. *Coast of part of Virginia and part of North Carolina.* FIELD-WORK.—To continue the triangulation of *Pamplico Sound,* and to make the requisite astronomical and magnetic observations; to continue the topography of the western shores and estuaries of *Pamplico Sound;* to continue the in-shore and off-shore hydrography of this section; to continue soundings in *Currituck* and *Pamplico Sounds,* and their estuaries, and to make observations on the tides and currents. OFFICE-WORK.—To make the computations and reductions; to continue the drawing and engraving of Nos. 42, 43, and 44, (*Pamlico Sound and estuaries;*) of No. 45 and No. 46, (*coast from Cape Hatteras to Cape Lookout;*) and of charts of the *Neuse River and Pamplico River,* will require 38, 000

SECTION V. *Coast of South Carolina and Georgia.* FIELD-WORK.—To make the requisite astronomical and magnetic observations on the coast of *Georgia;* to extend the topography from *Winyah Bay to Cape Romain;* to complete the topography and to sound the interior water passages between *Charleston and Savannah,* and continue off-shore hydrography and the tidal observations. OFFICE-WORK.—To make the computations; to continue the drawing and engraving of the General Coast Chart No. VII, (*from Cape Romain to St. Mary's River;*) of Coast Charts No. 56 and No. 57, (*from Savannah River to St. Mary's River;*) and of charts of *Altamaha Sound, St. Andrew's Sound,* and the inland tide-water communication on the coast of *Georgia,* will require 40, 000

SECTION VI. *Coast, keys, and reefs of Florida.* FIELD-WORK.—To determine the longitude of several points on the west coast of *Florida;* to continue the triangulation

and topography from *Matanzas Inlet* southward to *Mosquito Inlet;* to continue the survey of *Tampa Bay;* to continue the hydrography of the *Straits of Florida* and explorations of the *Gulf Stream;* to complete the hydrography of the *Bay of Florida*, and to make tidal and magnetic observations. OFFICE-WORK.—For computing from field observations; to continue the drawing and engraving of Off-shore Chart No. XI, (*western part of Florida Reef, including the Tortugas;*) of Coast Charts No. 75 and No. 76, (*from Caloosa Entrance to Tampa Entrance;*) and complete Coast Charts No. 70 and No. 71, (*Key West to Tortugas,*) will require $40,000

SECTION VII. *Western coast of Florida, peninsula north of Tampa Bay, and coast of West Florida.* FIELD-WORK.—To continue the triangulation and topography of *Chattahoochee Bay;* and of the Gulf coast eastward and westward, and to make such astronomical and magnetic observations as may be required; to survey and sound the entrance to the *Suwanee River;* to complete the hydrography of *St. George's Sound;* and to continue the tidal observations. OFFICE-WORK.—To make the computations from field-work; to continue the drawing and engraving of Coast Charts No. 82 and No. 83, (*from Ocilla River to Cape San Blas;*) and of General Coast Chart No. XIII, (*Cape St. Blas to Mobile Entrance,*) will require 30,000

SECTION VIII. *Coast of Alabama, Mississippi, and part of Louisiana.* FIELD-WORK.—To continue the triangulation from the *Mississippi Delta* westward, and to make the astronomical and magnetic observations required in this section; to commence triangulation for the survey of the *Mississippi* and its tributaries in the vicinity of *St. Louis*, *Cincinnati*, and such other points as may be practicable; to continue the survey of the *Mississippi* between the head of the *Passes* and *New Orleans;* to continue the hydrography within the same limits; and that of *Lake Borgne* and *Lake Pontchartrain;* and to make tidal observations. OFFICE-WORK.—To make the computation pertaining to field-work; to continue the drawing and engraving of the General Chart No. XIV, (*Gulf coast between Mobile Point and Vermilion Bay;*) of Coast Charts No. 91, (*Lake Borgne and Lake Pontchartrain;*) No. 92 and No. 93, (*Chandeleur Islands to Southwest Pass;*) and No. 94, (*Mississippi Delta,*) will require 50,000

SECTION IX. *Coast of part of Louisiana and coast of Texas.* FIELD-WORK.—To measure a base line of verification; to continue the triangulation and topography of *Madre Lagoon* from *Corpus Christi Bay* southward; to complete the hydrography of *San Antonio and Espiritu Santo Bays;* to continue the off-shore hydrography, and to make the requisite tidal observations. OFFICE-WORK.—To make the office computations; to complete the engraving of Coast Chart No. 107, (*Matagorda and Lavaca Bays;*) to continue the drawing and engraving of No. 108 and No. 109, (*Gulf coast from Matagorda to Corpus Christi Bay;*) to engrave the resurvey of *Aransas Pass*, and to continue the drawing and engraving of General Chart No. XVI, (*Gulf coast from Galveston to the Rio Grande,*) will require 35,000

Total for Atlantic coast and Gulf of Mexico 391,000

The estimates for the *Pacific coast* of the United States are intended to provide for the following progress in the survey:

SECTION X. *Coast of California.* FIELD-WORK.—To make the required observations for latitude, longitude, and azimuth at stations of the primary triangulation, and to make magnetic observations; to connect the islands of *Santa Cruz*, *Santa Rosa*, and *San Miguel* with the coast triangulation; to execute the topography of the same and continue the topography of the coast from *Buenaventura* to *Santa Barbara*, and from *Point Concepcion* northward; to continue the off-shore hydrography of the coast of *California*, and the tidal observations. OFFICE-WORK.—To make the computations of observations, and to continue the drawing and engraving of the maps and charts made in the field; also, for the operations in—

SECTION XI. *Coast of Oregon and of Washington Territory.* FIELD-WORK.—To continue the astronomical and magnetic observations in this section, and the triangulation, topography, and hydrography in *Washington Sound* and in *Puget Sound;* to

continue the survey of the *Columbia River;* and to make such special surveys as may be called for by public interests on the coast of *Oregon* and *Washington Territory;* and to continue the drawing and engraving dependent on the field-work and hydrography, will require $275,000

For publishing the observations made in the progress of the survey of the coast of the United States, per act of March 3, 1843, the publication to be made at the Government Printing Office 5,000

For repairs and maintenance of the complement of vessels used in the survey of the coast, including the purchase of new vessels to replace those too old for repairs, per act of March 2, 1853 45,000

For pay and rations of engineers for the steamers used in the hydrography of the Coast Survey, no longer supplied by the Navy Department, per act of June 12, 1858..... 5,000

The annexed table shows, in parallel columns, the appropriations made for the fiscal year 1869–'70, and the estimates now submitted for the fiscal year 1870–'71:

Object.	Estimated for 1870–'71.	Appropriated for 1869–'70.
For survey of the Atlantic and Gulf coasts of the United States, including compensation of civilians engaged in the work, per act of March 3, 1843........	$391,000	$275,000
For continuing the survey of the Pacific coast of the United States, including compensation of civilians engaged in the work, per act of September 30, 1850........	275,000	175,000
For publishing the observations made in the progress of the survey of the coast of the United States, including compensation of civilians engaged in the work, per act of March 3, 1843, the publication to be made at the Government Printing Office........	5,000	2,000
For the repairs and maintenance of the complement of vessels used in the survey of the coast, per act of March 2, 1853........	45,000	30,000
For pay and rations of engineers for the steamers used in the hydrography of the Coast Survey, no longer supplied by the Navy Department, per act of June 12, 1858........	5,000	5,000
Total........	721,000	487,000

SOLAR ECLIPSE OF AUGUST 7, 1869.

An eclipse has very rarely occurred offering such opportunities for making all the observations that could be desired, in connection with such phenomena as were presented on the afternoon of the 7th of August. Its path running over a great belt of inhabited country, much of it accessible by railroads, supplied with telegraph lines for independently ascertaining the longitudes of stations for observers, and thus bringing all the value of the observations to bear on the elements of the lunar orbit; an intelligent population greatly interested in the scientific aspects of the event, and ready to render aid in procuring the desired results; and the intrinsic utility of the proposed observations, left nothing to be wished for, but success in making them. Fortunately, too, among the inspiring circumstances, was the concurrence of the season of the year in which might be expected the least general obscuration of the view in consequence of cloudy weather. In such a case it is nothing less than a duty owing to civilization that everything in our power and within our means should be done to make the observations as complete as possible.

On the part of the Coast Survey, arrangements for observing this eclipse were made primarily and chiefly with a view to obtaining observations of precision for the purpose of correcting the elements of the lunar tables. Such observations include the times of contacts near the central line of the eclipse, from which times the coincidence of the sun's and moon's centers in longitude is obtained; the duration of totality near the edges of the shadow from which its precise limits, and hence the moon's position in latitude, are derived, as well as the moon's diameter. Furthermore, from observation of the contacts at stations widely apart on the central line, yet referable to each other by their true geographical positions, a value of the moon's distance from the earth may be inferred free from certain sources of error by which ordinary observations are affected.

With these purposes in view, therefore, as well as to increase the chances of favorable sky, the observing stations were selected so as to cover the greatest possible range on the path of the eclipse, within practicable limits of accessibility. Assistant George Davidson observed in Alaska Territory, at a station accessible from Sitka, where the eclipse commenced about noon, and secured such data as the partial interference of clouds would permit. An abstract of the details connected with his operations will be given further on, under the head of Section XII.

On the east side of the Rocky Mountains four stations were selected for the observations: Des Moines, in Iowa, the most western point accessible by railway and the telegraph; Springfield, in Illinois; Shelbyville, in Kentucky; and Bristol, in Tennessee, the last-named station being the most eastern point at which the last phase of the eclipse could be well observed, on account of the sun's approach to the horizon. On the coast of North Carolina, the eclipse ended about 6 o'clock in the evening.

As it appeared altogether probable that the precise times of the principal phases could be inferred more accurately from instantaneous photographs taken in quick succession near the instant sought, than they could be noted by eye observations, arrangements were made for obtaining such results as far as instrumental means were available. The party organized to observe at Springfield under my immediate direction, in charge of Assistant Charles A. Schott; and that at Shelbyville, directed by Professor Winlock, of Cambridge Observatory, and Assistant George W. Dean, were provided with photographic apparatus attached to equatorially mounted telescopes. The particulars connected with the operations at those stations will be detailed, for Shelbyville, in Section VII, and for Springfield, in Section VIII. In the same section will be stated, in a general way, the observations made at Des Moines, under the direction of Assistant J. E. Hilgard; and in section IV, the observations made by Assistant Richard D. Cutts, at Bristol, on the north boundary line of Tennessee.

The reports at length, giving the results found at each of the five stations, will be found in the Appendix No. 8.

MARINE STRUCTURES.

Reports on the progress of the Coast Survey in past years refer to frequent instances in which advice has been officially sought in regard to the effect, for good or ill, of proposed marine structures. In other cases, in advance of previous action, the counsel of my predecessor, in conjunction with others whose interest in the public welfare could not be doubted, was sought at the outset of movements intended for the preservation or for the improvement of harbors or channels. Thus, many surveys have been made in this branch of the service of the government with direct reference to the solution of most important questions. Among the officers who have been engaged in this collateral duty, Assistant Henry Mitchell has been distinguished for his capacity, industry, and patience in researches calculated to throw light upon problems which can be solved only after comprehensive reviews of all the conditions and circumstances that pertain to them. The tides, the currents, the configuration which modifies them, have been his familiar studies for some years, and to these have been added, from time to time, the general knowledge of what has been done abroad. On account of the evident expediency of fostering inclinations, the fruits of which are so often required in these great practical discussions, and in the successful combination of observation and theory, Mr. Mitchell was permitted to examine, personally, the marine structures of Europe. This was done with the sanction of the Secretary of the Treasury. The results have fully justified the anticipations, and information has been collected which will be of unquestionable value in the decision of questions now pending. Assistant Mitchell was cordially and hospitably received by the leading marine engineers of Scotland, Belgium, Holland, and France, and freely admitted to the unrestricted and confidential inspection of their works, and terminated his inquiries at the Isthmus of Suez, where every opportunity was afforded him for thorough inquiry, and his progress through the canal facilitated with unstinted generosity. An abstract of his report on the great work there, and of its probable success, has already been given to the public. Mr. Mitchell returned to the United States in February, 1869, and will prepare reports upon his observations as rapidly as will be consistent with his constant occupation in the difficult questions of his office.

PART II.

Under heads corresponding to the number of sections of the survey will now be noticed briefly the work done by each of the field parties. Mention of the separate surveys will, as usual, be made in geographical order, beginning with one in the vicinity of the northeastern boundary of the United States, and closing on the Atlantic side with a reference to work done on the coast of Texas. On the Pacific side the order will be reversed, terminating with notices of work done incidentally on the coast of Alaska.

In the course of the present year the triangulation has been continued in all the sections of the Atlantic coast, except in the two embracing the eastern coast of Florida and the coast of Texas. Eleven parties have been employed in this duty, apportioned north and south, according to the necessities of the survey and to the season most favorable for the progress of the field-work. At the commencement of the war the survey was necessarily suspended on the Lower Atlantic and Gulf coasts, and was left at many points in an incomplete and unsatisfactory condition. The resumption of operations after so long an interval has involved, as might be expected, additional labor and expense. The loss of signals and of station-marks at places in which the surveying and hydrographic parties had not been able to follow immediately on the heel of the triangulation have rendered renewal or subsidiary work indispensable. Much of this has been already accomplished, while at the same time the geodetic work has made positive and important progress. A more thorough system is being gradually introduced, as far as practicable, in the field operations, which will result in uniformity in the records and mode of observing, and in the prompt closing, by verifications of every series to be hereafter observed, at intervals depending on the size and character of the triangulation. For many valuable suggestions, which have been available in restoring the efficiency of this branch of the work, I am indebted to Assistant Richard D. Cutts, whose promptness and energy are always to be depended upon. In addition to the operations of his own party in Sections III and IV, Mr. Cutts personally reviewed, in the course of the season, the field-work of most of the parties engaged in secondary triangulation.

In topography, questions of method and style of work, representation of details, extent of marginal surveys, and the co-operation of adjoining parties, have been, as heretofore, subjects of consultation and advisement between Assistant Henry L. Whiting and the several topographers in the field. Detached portions of work, unavoidably omitted in former years, have been completed; and connected progress, where the surveys are extending over new grounds, has been assured. Special surveys, of which the general scheme was projected by Mr. Whiting, will be referred to under Sections I and II. The study of prospective work and questions connected with the details of arrangement for the parties, the field examination and test of the surveys, and of the maps when completed, are among the duties continued in his charge.

The details pertaining to the party arrangements for hydrography, the verification of the charts, sailing lines and sailing directions, and the care and outfit of vessels, have been, as heretofore, in charge of the hydrographic inspector, Captain C. P. Patterson. In the present condition of the vessels, unfit for sea duty as most of them are from age, the field and hydrographic parties could not be kept in service without the expedients suggested by his experience in nautical affairs.

On the Pacific coast, comprised under Sections X and XI of this report, the operations of all the parties have been reviewed by Assistant George Davidson. Passing along the whole of the western coast within the present year, on his way to Alaska, Mr. Davidson took the opportunity to add to the extensive knowledge which had been previously embodied in his comprehensive Coast Pilot. In the further interest of general navigation his researches have also included the coast of Alaska; and on going there in July last to occupy an astronomical station during the solar eclipse, which occurred in August, the visit was improved for the verification of his Coast Pilot for that region. The part already published contains directions for navigating the coast of Alaska from the southern boundary northward to Cook's Inlet. At this date the preparation of the remaining part is far advanced towards completion. The third edition of his Coast Pilot for the coast of California, Oregon, and Washington Territory, first published in the year 1858, is now ready for issue.

An abstract of the observations made by Assistant Davidson in Alaska will be given under the head of Section XII. The details of work done by his own party on the coast of California and Oregon, and by the parties assigned to duty at sites pointed out by his knowledge of the requirements of the service, will be stated under Sections X and XI.

In the notices which follow only general facts in regard to the work will be mentioned. The distribution of the field parties and the kind of work in which each one of them was employed in the course of the year terminating with November, 1869, will be stated in a concise form in Appendix No. 1.

SECTION I.

ATLANTIC COAST OF MAINE, NEW HAMPSHIRE, MASSACHUSETTS, AND RHODE ISLAND, INCLUDING SEA PORTS, BAYS, AND RIVERS. (SKETCHES NOS. 2 AND 3.)

Topography of the St. Croix River, Maine.—After closing work at another site in this section, Assistant W. H. Dennis resumed the plane-table survey of the shores of the St. Croix River at the end of July. About two miles below Calais a junction was made with previous work, and from thence the survey was continued northward to a point about nine miles above the town. Both shores of the river were included, and also the shores of Oak Bay, to a distance of two miles and a half. The plane-table work done (Sketch No. 2) shows a large amount of detail, the country being quite thickly settled, and the hills along the shores varying in height, up to five hundred feet. The following is an abstract of the statistics of the survey:

Shore-line traced	22	miles.
Roads	35	miles.
Area of topography, (square miles)	17¼	miles.

Mr. O. H. Tittman served acceptably as aid in the topographical party.

Assistant Dennis made a special examination in August with reference to the expediency of re-establishing a light which had been discontinued in the St. Croix River. As a result he recommended that a light should be maintained on De Mont's Island during nine months of the year, the commerce fully warranting such action. The report on the subject was transmitted without delay to the chairman of the Light-house Board.

This party passed the early part of the year on the coast of Georgia, and has now resumed duty in Section V.

Hydrography of Isle au Haut Bay, Maine.—The hydrographic service performed in Isle au Haut Bay was done in the latter part of the working season, terminating on the 23d of October, by the party of Assistant Charles Junken, in the steamer Endeavor. The part of the bay sounded (Sketch No. 2) lies between Eagle Island on the north, and Brimstone Island on the south. Eastward the soundings were extended from North Haven and Vinal Haven as far as Deer Island, and to the southward of it somewhat further. Within the limits of the work done this year the principal ledges developed are the following:

Saddleback Rock Ledge, with four feet at low water, about a mile from Saddleback light.
Fox Island Reef, with twenty-two feet at low water, a mile and a half from the same light-house.

The statistics of this work will be given in aggregate, with the notice of work done by the same party under the next head. Only the middle part of the bay was sounded, leaving for future development the parts adjacent to the shore-line of islands which bound the bay. Of most of these the outlines have not yet been traced.

Hydrography of Hurricane Sound and approaches, Penobscot Entrance, Maine.—This work connects with the hydrography of Vinal Haven, which was done last year by the party of Assistant Junken. The soundings were resumed on the 22d of July, and after including Hurricane Sound, (Sketch No. 2,) and, connected with it, "The Reach," which passes into Isle au Haut Bay, they were extended westward to the vicinity of Monroe Island, where a junction was made with the hydrographic work of the present season done by Assistant Webber. About a mile and a half east-southeast from the island just named, the depth was found to be 84½ fathoms, which is more than has been found elsewhere in Penobscot Bay or in its approaches. Numerous ledges lying between the Bay Ledges and Vinal Haven were developed. One of these is a mile and a quarter south of

the Bay Ledges, in 11 feet at low water, and its existence is but little known. White Island Shoal, a mile and a quarter west of Little Hurricane Island, has 10 feet at low water. Black Point Ledge, one-third of a mile west of Black Point, has only 9 feet; and a rock developed in Leadbetter's Narrows has on it but $2\frac{1}{2}$ feet at low water. In the "Reach," Creed's Rock, which is exactly in the channel-way, off Creed's Beach, was found to have 6 feet at low tide. Other obstacles of like character, are marked on the hydrographic sheet.

Messrs. W. I. Vinal and G. W. Bissel served as aids in the hydrographic party. In the following statistics are included the particulars of work done by the party in the Endeavor to the eastward, notice of which was taken under the preceding head:

Signals erected	35
Miles run in sounding	876
Angles	11,810
Number of soundings	24,427

The party of Assistant Junken is now in readiness to resume hydrographic duty in Section V.

Prospect Harbor light.—In order to meet a question proposed from the Light-house Board in regard to the necessity for re-establishing the light formerly maintained at Prospect Harbor, on the coast of Maine, Assistant Junken made an examination of the place in October. As a harbor of refuge for vessels coming from the eastward, Prospect Harbor is of considerable importance. The re-establishment of the light was, in consequence, recommended, and the reasons therefor have been made known to the Light-house Board.

Hydrography of Penobscot Bay, Maine.—At the upper limit of the work mentioned in a preceding notice, Assistant F. P. Webber, with a party in the schooner Joseph Henry and steam launch Sagadahoc, took up, and extended northward, the soundings in Penobscot Bay. The work done (Sketch No. 2) makes the hydrography continuous between the Fox Islands and the harbors of Camden and Rockland. Tides were observed in the first named harbor while the soundings were in progress. On the lines run, depths were found varying from 20 to as much as 66 fathoms. Very few sunken ledges were developed, but several that are partly bare at low water. Of these, Carr's, or Egg Rock Ledge, was found to be in only 4 feet at low water, and Compass Island Ledge in 7 feet of water. These are small, and run up in points, and, having deep water immediately about them, must be regarded as dangerous.

Sub-Assistant F. D. Granger was attached to the hydrographic party, and prosecuted work in charge of the launch. Mr. R. B. Palfrey served as aid. Soundings were commenced on the 22d of July, and closed on the 18th of October, with the following result in statistics:

Signals erected	15
Stations determined	19
Miles run in sounding	490
Angles measured	3,872
Number of soundings	13,297

The office work of the party was kept up, as far as possible, with the work afloat, and soon after the vessels returned to Portland, the resulting hydrographic sheet was forwarded to the office.

This party had passed the early part of the year in service in Section VIII, and preparations have been made to resume the work which was discontinued there on the approach of summer.

Coast Pilot, from Penobscot Bay to Boston Harbor.—The advance toward completion, of the survey of the Atlantic Coast and harbors intervening between Penobscot Entrance and Boston now warrants the issue of a comprehensive publication for the benefit of all who may have occasion to navigate the coast of New England. As ports on other parts of the coast become connected in the progress of the hydrography, it is intended to issue Coast Pilots of the character now to be brought under notice.

The duty of preparing the manuscript for the Coast Pilot of Section I was assigned to Assistant J. S. Bradford, and on that he was engaged from November, 1868, until the latter part of June of the present year, under the immediate supervision of the hydrographic inspector. Instructions

were then given to verify the manuscript directions which Mr. Bradford had prepared by personal inspection of the ports and sailing lines. No vessel belonging to the Coast Survey being available, the schooner S. L. Morgan was hired for the service, and was accompanied by her owner as sailing master. Thus provided, Assistant Bradford proceeded from Boston eastward along the coast, and visited every harbor of consequence as far in that direction as the entrance to the Penobscot. The sailing directions which he had compiled were carefully verified, as also the descriptions of the coast and shore features. Such errors as became evident were corrected; and what showed as omissions on the published charts were noted and supplied. The buoy system in each of the harbors was incidentally examined, and separate notes were made in regard to them for the information of the Light-house Board.

It is a gratifying proof of the accuracy of detail with which our topographical maps have been made, that in only rare instances did Mr. Bradford find occasion to alter, from personal observation, the previously written descriptions of islands and shores which he visited for the first time after the compilation of the manuscript, and for which he had no other data than maps in the Coast Survey Office.

In addition to his general duties in this section, Mr. Bradford made a special examination of Salem Harbor, Massachusetts, with reference to the necessity for a light-house on Fort Point. His report in favor of the establishment of an additional light was transmitted to the Light-house Board before the close of August.

Scituate Harbor, Massachusetts, was also examined to determine the expediency of relighting the Scituate light-tower.

After completing the verification of the Coast Pilot, on the coast of Maine and New Hampshire, Mr. Bradford returned with his party to Boston, and during the remainder of the season made a thorough examination of Boston Bay and Harbor, with reference to the descriptive features. This included also Town River, and Weymouth Fore and Back Rivers, above the drawbridges.

On the 19th of October work was closed in the field. Assistant Bradford then repaired to the Coast Survey Office, where he is now engaged in bringing up the results of the season's operations, and in preparing the manuscript of a Coast Pilot, which will be descriptive of the coast between Boston and New York.

The imminent peril in which the schooner Morgan was placed by the great storm which ranged the coast of New England on the evening of the 8th of September, elicited a conspicuous instance of personal intrepidity. At 9 p. m., the storm having raged about one hour, the starboard anchor chain snapped, and the vessel dragged swiftly to the ice-house wharf in Deep Cove, George's River, Maine. The stern-boat of the Morgan struck against the piling, and was dashed into splinters. At a moment of the greatest peril, Mr. Lucien B. Wright, one of the aids in the party, climbed along the main boom, and, at the risk of his life, reached the wharf with the end of a line. When this was done, the boom was sweeping across the dock, sometimes ten feet above it, and sometimes coming violently down to within a few inches of the planking. Assistant Bradford passed by the stern davits as the vessel swung in, and jointly they succeeded in hauling ashore a six-inch rope and making the schooner fast. This was after 10 p. m., at which time the force of the storm was such as to make it impossible to stand anywhere on the wharf. Assistant Bradford and Mr. Wright, on their hands and knees, performed the important service of securing the vessel fore and aft. The Morgan was the only vessel then in the vicinity that was not blown on shore, high and dry.

Topography of George's River, Maine.—The camp of Assistant F. W. Dorr, who was directed to survey the entrance of George's River, was pitched at Deep Cove, in the middle of July. A few miles of the neighboring shore line had been traced by Assistant Hosmer in 1867, but none of the details had been mapped. Mr. Dorr at once took up the survey of the lower part of the river, and so prosecuted the work as to connect very satisfactorily with the survey previously made to the eastward by Assistant Dennis in the vicinity of Mosquito Harbor, and with that of Assistant Hosmer, which includes the western side of George's River.

The survey of Mr. Dorr embraces both shores of the river, (see Sketch No. 2,) from the Lower Narrows to its mouth; and also Gay's, Teal's, Bar, Eagle Island, and Great and Little Caldwell Islands, which lie off the entrance to the river. The topographical sheet includes also the northeastern shore of Herring Gut Harbor and Mosquito Island. The shore line traversed, like

most on the coast of Maine, is rocky, rough, and very irregular. Except near the main roads the interior is covered with a stunted growth of trees. The elevations are abrupt and without any approach towards regularity. As a consequence their representation by the customary method of curves proved difficult and tedious.

With the notable exception which will be alluded to before the close of this notice, the weather throughout the season was unusually fine, with less than the ordinary occurrence of fogs and wind. The field-work was closed on the 1st of October. A synopsis of statistics is here given, as taken from the report of Mr. Dorr:

Shore-line surveyed	52 miles.
Streams	9 "
Roads	33 "
Area of topography, (square miles)	16 "

Sub-assistant H. M. De Wees, in consequence of the ill health of Mr. Dorr during the former part of the season, was assigned to the party in August, and subsequently he conducted the plane-table survey. Mr. G. C. Schaeffer, jr., served as aid. The party was previously employed in Section IV, and will be engaged in the same section during the ensuing winter.

The camp of Assistant Dorr suffered considerably from the furious gale of the 8th of September, which, as in other places where it raged, struck without warning at 9 o'clock in the evening. Three of the tents were prostrated instantly, and those not blown away were more or less damaged before they could be taken down. The sea broke in a solid mass over the wharf adjoining the camp, and one of the ice-houses on it was blown down. Several houses and barns in the immediate neighborhood were shattered by the force of the storm. It is the general testimony of assistants serving in this section that on no part of the Atlantic or Gulf coast have they at any time experienced a storm of greater force or more sudden in its action.

Topography near South Thomaston, Maine.—The party of Assistant Dennis, before taking the field in the vicinity of the northeastern boundary, completed a sheet of topography which was left unfinished at the close of last season. This includes the eastern side of George's River, in the neighborhood of South Thomaston, and employed the party from the 1st until the 25th of July. The shore-line had been previously traced, as was mentioned in my report of last year. In the early part of the present year Mr. Dennis and his aid, Mr. Tittmann, were on duty in Section V, and the mention of their service will be found under that head. The party has resumed work on the southern coast.

Topography and hydrography of the Kennebec River, Maine.—Early in August Assistant C. H. Boyd took up the plane-table survey of the shores of the Kennebec, on Merrymeeting Bay, in the vicinity of the mouth of the Androscoggin, (Sketch No. 2,) where he joined with the topography of a previous season. Provision was made at the same time for commencing the hydrography as soon as shore-line could be furnished. Observations were made on the currents, and lines of levels were run between the tide-gauges. When these preliminaries were complete, the shore-line survey and details of topography were extended up the river. One plane-table sheet having been filled, the soundings were made corresponding to it; and thus the work was pushed upward till the 6th of November, when the survey was closed for the season at a point above Richmond.

Assistant Boyd was aided in this section by Mr. J. G. Spaulding, and in the latter part of the season by Mr. J. Hergesheimer. The results of work are expressed in the following statistics:

Shore-line surveyed	70 miles.
Roads	24 "
Area of topography, (square miles)	14 "
Sextant angles	510 "
Number of soundings	4,577 "

The plane-table sheet includes Swan Island, in the Kennebec. At the outset of the surveying season Mr. Boyd was engaged in duty that will be mentioned under the head of Section VIII. He is now about to return to the same field of service.

Topography of Mericoneag Sound, (Casco Bay,) Maine.—The detailed plane-table survey of the shores of Casco Bay has been essentially completed by Assistant A. W. Longfellow. After setting

up the requisite signals, he resumed work on the 8th of July, with a party in the schooner Meredith. The western side of Sebaskahegan Island was surveyed, and the margin of the main land north of it in the direction of Brunswick. On the same sheet are represented the surface features of the shores of Mericoneag, or Harpswell Sound, and the topography of the head of Middle Bay, of Long Reach, and of Ewin's Narrows, the shore-line of which was furnished in advance for the use of the hydrographic party. The character of the topography, as represented by the plane-table sheet, is quite intricate. In general reference to it, the following remarks occur in the report of Mr. Longfellow: "The mica slate formation, characteristic of the coast of Maine, gives directly the form and relief of the ground, being very thinly covered with soil. The stratification stands nearly vertical, or upon its edge, forming long, narrow, parallel ridges, rising sometimes to an elevation of two hundred feet, and, being mostly wooded, these ridges offer great obstacles to the topographer. The direction or trend of the strata on Sebaskahegan, and on the shores of New Meadows River generally, is true north and south, showing in this respect a marked deviation from its direction in the southern part of Casco Bay, as about Portland, where the course of the strata is with uniform precision northeast and southwest. This shows, in a distance of only twenty miles, a deflection of the rock strata of forty-five degrees toward the north.

"On the remarkable island of Sebaskahegan, as at Phipsburg and West Bath, on the east shore of New Meadows River, there is much intrusion of coarse granite through the slate forming the summits, which modifies but does not soften the contour of the ridges, only rendering them more rough and broken.

"The continuity of direction of the rock strata in Casco Bay is a marked feature, and is well shown upon the published Coast Survey chart, where the entrances from the ocean and the sounds are seen to be simply breaks through the parallel mica slate walls. This persistence of direction also indicates to the hydrographer where to look for the extension of reefs and shoals under water."

The party continued in the field until the 11th of November, when the details of the plane-table sheet were completed. The shore-line had been traced in a previous season, and is marked on the Progress Sketch No. 2.

Hydrography of Ewin's Narrows, Long Reach, and Doughty's Cove, (Casco Bay,) Maine.—At the end of June Sub-Assistant Horace Anderson reached Harpswell, and after setting up a tide-gauge, sounded out Ewin's Narrows, and the adjacent waters of the upper part of Casco Bay, known as Long Reach, and Doughty's Cove, and also the deep channel between the Reach and Gurnet Bridge. This channel is narrow and intricate, and can be used by no vessels larger than fishing boats.

A second tide-gauge set up at Flying Point, to the westward, was watched for twelve hours in observations simultaneous with those at Ewin's Narrows, after which high and low waters were observed at Flying Point during thirty days. Meanwhile Mr. Anderson made the soundings needed in Maquoit Bay and Middle Bay, completing the hydrography on the 24th of July. Mr. W. H. Stearns was employed in this work temporarily as recorder. Assistant Longfellow furnished the plane-table points needful for sounding. The site of work is shown on Progress Sketch No. 2. The results have been subsequently engraved and added to the chart of Casco Bay. A statement of statistics is appended:

Miles run in sounding	81
Angles measured	694
Number of soundings	8,198
Signals determined	63

After completing this work, Sub-Assistant Anderson took up hydrographic duty in the dependencies of Portland Harbor. In the early part of the surveying year he was employed in Section IX, and is now completing arrangements for hydrographic duty in Section V.

Special survey of Portland Harbor, Maine.—This minute survey, for which means were provided by the city authorities of Portland, has been completed, and the sheets, on a large scale, are well advanced in the hands of the draughtsman. Assistant J. A. Sullivan resumed the subsidiary triangulation on the 10th of May, and continued uninterruptedly during the season the determination of points required for the topographical and hydrographic work, which was taken up in the middle of July. Mention will be made presently of the detailed plane-table surveys by Assistants J. W. Donn and Charles Hosmer, and of the soundings by the party of Sub-Assistant Horace

Anderson. The triangulation was sufficiently advanced by the first of June to enable Mr. A. Lindenkohl to resume his topographical work of the previous season on the eastern part of the peninsula. Of that vicinity the sheet was projected to include about one-third of the city, but the part embracing Munjoy Hill was finished last year. Mr. Lindenkohl completed the remaining part of the sheet, and then returned to Washington.

Assistant Sullivan was aided by Mr. J. N. McClintock. By means of the spirit level a series of bench marks was established at convenient distances on the ground to be surveyed, so as to facilitate the subsequent work of contouring. In addition to providing points, Mr. Sullivan conducted the details of the special survey, and took charge of the plane-table and hydrographic sheets for final compilation. The statistics of his work of triangulation are thus given:

Signals erected	68
Stations occupied	60
Points determined	51
Number of observations with theodolite	16,000

In addition to the data thus furnished, Mr. Sullivan computed for topographical purposes the positions of one hundred and ten subsidiary points.

This survey, in its plan and subsequent development, has been reviewed by Assistant Whiting. In closeness of detail and accuracy it is perhaps unsurpassed. No other practical method and style of work likely to be completed in the same time with a limited force could have produced equal results.

Assistant Sullivan has been directed to take charge of the surveying party which has been assigned, at the request of the honorable Secretary of the Navy, to accompany the expedition for exploring the Isthmus of Darien for the route of a ship canal.

Mr. Hosmer reached Portland on the 24th of June, and during the month following engaged in computations resulting from the triangulation. He then took up field duty with the plane-table, and prosecuted the topographical survey until the 9th of October, suspending it at that date temporarily for the completion of a sheet of work, of which mention has been made under a preceding head. After resuming at Portland, Assistant Hosmer continued the detailed survey, and filled the three topographical sheets which had been projected for him by the 13th of November. These represent, in full detail, the central and northwestern part of the city, the north shore of Back Cove, and the shore of Cape Elizabeth between the Bug Light-house and Portland Bridge. The shore line of Back Cove was traced, by the aid of Mr. McClintock, during the absence of Assistant Hosmer at Thomaston, Maine.

Before taking up service at Portland Mr. Hosmer had been employed in field duty in Section II, and earlier in Section V. He is now under instructions to resume topographical work on the coast of South Carolina.

The expenditures incurred in prosecuting the special survey at Portland were defrayed by the city authorities.

Assistant Donn commenced work with the plane-table in the middle of July, and surveyed the part of the city which lies along Fore River and the canal basin. Here the contour of the ground was carefully determined by leveling, and the curves traced on the topographical sheets show the surface elevations. Two large maps were thus filled with details. A third sheet contains Mr. Donn's survey of the northwestern part of the city. He traced also the shore line of Portland Harbor on the south side from Portland Bridge to the railroad bridge, and both banks of the Fore River and Stroudwater, for the use of the hydrographic party. Much of the ground represented by the first two sheets is greatly broken, and the topographical details are, in consequence, exceedingly intricate in character. Their successful delineation is strong evidence of the completeness of the method adopted at the outset of the survey. After inking his plane-table sheets Assistant Donn resumed duty in Section III, where he had been previously engaged.

The hydrography needed for the completeness of the special survey was conducted by Sub-Assistant Anderson, after the completion of soundings in the upper part of Casco Bay. At Portland three tidal stations were established about the middle of August. Nearly twenty thousand soundings were made and recorded. These fill four hydrographic sheets, of which three represent the Fore River and Stroudwater, and another the Back Cove. The hydrography was finished on the 11th of October.

In the early part of the year Mr. Anderson was employed in Section IX. He is now under instructions for duty in Section V.

Topography between Kennebunkport and Wells, Maine.—The plane-table survey of the coast of Maine was resumed at Ogunquit, by Assistant Hull Adams, on the 5th of uly. Working northward and eastward the coast line was traced and the several river mouths that intervene between the limit of work and Kennebunk River, beyond which the survey was extended about a mile. The detailed topography was carried back to the road, which here in its course from Portland to Portsmouth, New Hampshire, runs generally parallel with the coast. Kennebunkport is included in the survey and the river in its vicinity, as also the lower parts of Moussam River and Little River, with the surface features between them, and Webhaunet River. In the field report it is remarked, as of interest, that the mouth of Moussam River has been twice changed by the action of the wind and sea, within the last sixty years. The present outlet was artificially made about thirty years ago, and is about midway between the former entrances. Mr. Adams marked on his topographical sheets the rocks that lie off the coast in this vicinity. He was efficiently aided by Mr. Eugene Ellicott.

Field-work was continued until the 6th of October, at which time the party had reached the following result in statistics:

Shore line surveyed	51	miles.
Roads	27	"
Marsh line	25	"
Area of topography, (square miles)	17½	"

By the exertions of Mr. Ellicott the camp of the party was preserved, with but little damage, on the night of the 8th of September, during the storm which pressed with great violence on the coast of Maine.

Longitudes: Cambridge, Omaha, Salt Lake City, and San Francisco.—The earnest co-operation of Professor Joseph Winlock, director of Harvard Observatory, has been given in the astronomical and telegraphic operations for determining the difference of longitude between the Atlantic and Pacific coasts of the United States. A clock and chronograph, and facilities for mounting the needful instruments, being assigned in January last, Assistant A. T. Mosman set up transit No. 5 and, under the general direction of Professor Winlock, arranged the preliminaries for exchanging star signals by means of the telegraph. The use of the lines going westward from Cambridge was given in the accustomed spirit of liberality by the officers of the Western Union Telegraph Company, on the application of Assistant George W. Dean, whose ultimate station for observing was at Salt Lake City, in Utah Territory. At San Francisco Assistant George Davidson procured the use of the telegraph line going eastward across the continent. Assistant Edward Goodfellow was stationed at Omaha, in Nebraska. Operations at the points intermediate between the coasts will be recited in notices of work done in Sections VIII, IX, and X. For the present notice will be taken of the observations made at Cambridge, as best conforming to the geographical order of the work in this and in previous annual reports. Assistant Mosman was aided at that station by Sub-Assistant F. Blake, jr.

Clock signals were successfully exchanged on the night of the 7th of February, between the observers at Cambridge and those at Omaha and Salt Lake City, and in the course of the month following that date signals were exchanged on ten nights between Cambridge and San Francisco. During the same interval eight nights were clear for observing at Salt Lake City, and seven nights for exchanges between Cambridge and Omaha. George F. Milliken, esq., superintendent of the Boston office of the Western Union Telegraph Company, and Mr. John Wright, one of the operators, gave their personal assistance at the Cambridge observatory, and much of the success that marked the operations is due to their untiring patience and perseverance.

In addition to the exchanges for difference of longitude, experiments were made on two nights through a double line of wire joining Cambridge and San Francisco, to determine the time of transmission, thirteen repeaters being interposed in the circuit. These trials were repeated on a night in April, and others for velocity were made under the direction of Professor Winlock, through a single wire, a simple pendulum beating seconds having been placed in the main circuit.

In obtaining the clock error and the instrumental corrections at Cambridge, Mr. Mosman

observed 397 stars on 33 nights, each over 15 threads; and 56 stars were observed over 25 threads, each for the thread intervals of transit No. 5. For inequality of pivots four sets of levelings were made.

At my invitation the directors of the observatories at Pittsburg, Pennsylvania, and Ann Arbor, Michigan, made due preparation and exchanged clock signals with the Coast Survey observers, while the observations for difference of longitude were in progress. The results of telegraphic exchanges on three nights with Professor Watson, of Ann Arbor, and of as many signals with Professor Langley, of Pittsburg, determine the longitudes of the two places named. The last-named observer proceeded to Cambridge subsequently, and made trials for the personal equation between himself and Mr. Blake. Two nights were also employed in determining the equation between Mr. Blake and Mr. Mosman.

After closing at Omaha the observations for longitude and latitude, mention of which will be made under the head of Section IX, Assistant Edward Goodfellow determined the geographical positions of Springfield and Mattoon, in the State of Illinois; of Burlington and Des Moines, in Iowa; and the longitude of Julesburg and Bushnell, in Nebraska, These determinations will be referred to under the head of Section VIII. The stations in Illinois and Iowa were occupied by observing parties on the 7th of August during the solar eclipse. Notice will be made in the same section of the results of their observations. The particulars are given in the Appendix, No. 8.

The operations at Salt Lake City and San Francisco will be stated under the head of Section X.

Azimuth at Cambridge, Massachusetts.—After closing observations connected with longitude at Cambridge, Assistant Mosman made others with transit No. 5, to determine the azimuth of a point about three miles from the observatory. This was at the time referred to the meridian by observing transits of close circumpolar stars over the micrometer. With five stars thirty-seven sets were observed on fifteen nights. Assistant Mosman and Sub-Assistant Blake then took up field duty, which will be noticed under the head of Section II, and were subsequently employed in special astronomical observations in other sections.

In October the line which had been determined in azimuth at Cambridge was referred by triangulation to the nearest primary station, (Blue Hill,) thus bringing the observatory into connection with the main triangulation of the coast. At the station "West Transit" in the observatory, six hundred measures of the angle between the meridian mark and Blue Hill were made on nine favorable days. The observations were completed on the 10th of November.

A base of forty meters in the observatory grounds was marked and used for reducing the station "West Transit" to the center of the dome, by a small triangulation. In making the transfer, two other stations were occupied, and seventy-two measures were made of the angles with a theodolite.

In November, just previous to his departure for the coast of France, Sub-Assistant Blake made some special observations in Section VIII. Assistant Mosman has been detailed to accompany the naval exploring expedition to the Isthmus of Darien.

The French telegraph cable.—The successful landing, after its departure from Brest, on the coast of France, of the western end of the French telegraphic cable on Duxbury Beach, coast of Massachusetts, on the 23d of July last, has an incidental connection with the work of the Coast Survey. Early in the period employed by the company in perfecting arrangements, I received a communication from Sir James Anderson, asking for information in regard to a suitable American terminus for the new cable, and citing the coast of Massachusetts as a desired general location. The details of this inquiry were assigned to Assistant H. L. Whiting, who made a careful study of the maps and charts of the coast indicated, and a personal examination of the ground offering advantages for the intended purpose. The salient points, as at Cape Ann and Cape Cod, were deemed objectionable; the first, on account of its rocky shores, and because of the uneven ledgy ground surrounding it; the second, by reason of its exposure and shifting sands, and the contingent anchorage of vessels in its vicinity. Massachusetts Bay, for the shelter afforded in nearing the coast, was considered more favorable, but the northern part of the bay from Cape Ann to Scituate does not present the desired ground. The southern part of the bay, though more inviting, is preoccupied by

numerous harbors, the local shipping of which demands most of the space available for anchorage. Just north of Plymouth Harbor, however, the last of the series of indentations in the outline of the bay, Mr. Whiting found a position in which several of the desired conditions concurred, but in the final choice of a location all the details of the inquiry were brought to a test. Duxbury Beach is the northern arm of Plymouth Harbor. Lying off the beach are two rocky shoals known as "High Pine Ledge" and "Howland's Ledge." While these ledges serve as warnings to keep away from the coast, they also serve as a shelter to the beach abreast of them, which is soft, smooth, sandy ground, without rocks and without shingle. The slope of the bottom from the beach at Duxbury to the mud bed of Massachusetts Bay is an even and regular decline. The course to sea is almost due east, passing between the "Race Point" of Cape Cod and the south end of Stellwagen's Bank, so as to clear George's Bank, which is still further out. These great advantages Mr. Whiting found to be strengthened by the fact that a mound, affording a good lookout, occurs about midway between the two protecting ledges before mentioned. The mound known as *Rouse's Hummock* is a conspicuous object, and in order to preserve it as a local landmark, it had been in a previous year purchased by the town authorities of Duxbury.

The published charts of the Coast Survey showing the seaward approach to Duxbury, together with the needful copies or tracings from the original field sheets of that vicinity, were furnished to the inquiring parties. With this data the cable fleet was enabled to approach the coast, pass Cape Cod, and steer directly for Duxbury Beach without the aid of a pilot. The fleet came to anchor off Rouse's Hummock before recognizing the signals made from shore to direct the movements of the vessels.

Longitude difference between Duxbury, Massachusetts, and Brest, on the coast of France.—By the liberal action of the board of managers of the French Cable Company, the use of their telegraphic cable, which lies across the bed of the Atlantic between Brest and St. Pierre, and from thence passes to Duxbury, Massachusetts, has been tendered free of charge for determining the longitude which it traverses. When this favorable resolve became known through the agent of the company, L. G. Watson, esq., the sanction of the Treasury Department was obtained for sending two observers to occupy a station at Brest and to exchange time signals with an observer at Duxbury. Assistant George W. Dean and Sub-Assistant F. Blake, jr., accordingly took passage at New York in the steamship Ville de Paris for Brest, on the 13th of November, and made due preparation there for the desired exchanges. Assistant Edward Goodfellow, aided by Mr. J. Laurence Wilde, at the same time proceeded to Duxbury, and have now in position the instruments requisite for determining the local time and the latitude of the station. Time signals were exchanged between Professor Winlock, at Cambridge, and Mr. Goodfellow, at Duxbury, on the nights of the 14th, 15th, and 23d of December, instant, and the prospect is good for an early and successful completion of the desired exchanges between Duxbury and Brest.

It is expected that Mr. Varley, the eminent European electrician, and Mr. Farmer, of Massachusetts, well known for his skill as a telegraphic engineer, will add to the interest and value of the operations by experimental tests for determining the very small interval of time required in passing signals to and from Brest and Duxbury.

Previous to his engagement in this service, Assistant Dean had been on active field duty in Sections VII and X, as will be stated under those heads in this report. Assistant Goodfellow was employed in Sections VIII and IX, and Sub-Assistant Blake had been on service in Sections I, II, IV, and VII.

Mr. Goodfellow reports that at Duxbury all facilities needed for the longitude operations have been cordially supplied by R. T. Brown, esq., the superintendent of the French Cable Company at that station.

Triangulation of Narragansett Bay, Rhode Island.—The subsidiary triangulation which was commenced last year at the entrance of Narraganset Bay was resumed by Assistant S. C. McCorkle, soon after his return from duty in Section VII. Work in the field was begun on the 15th of July, and the scheme laid out in my instructions was completed by the 28th of September. Between these dates Assistant McCorkle supplied all the points which were required for the plane-table party of Assistant Harrison, for the more rapid delineation of topographical details, and extended the network further to the eastward, and for the same object, so as to cover the entire

section of coast yet to be surveyed in Rhode Island. The work accomplished by the triangulation party this season may be summed up as follows:

Signals erected	17
Stations occupied	13
Angles measured	234
Number of observations	2,472

The records and computations of the work have been duly completed and forwarded to the office.

Mr. McCorkle is now under orders to return to Section VII, and resume operations on the coast of Western Florida.

Topography of Naraganset Bay, Rhode Island.—Before resuming the detailed plane-table survey on the western side of the bay, Assistant A. M. Harrison filled in some detached areas near Warren, Rhode Island, and Swansea, Massachusetts. These were needed for the symmetry of the chart, the engraving of which has been kept up with the field-work, as far as practicable. His party took the field early in June, and completed the desired details on the north shore of the bay by the end of that month. To these were added the new wharf-line at Bristol, and the positions of several rocks near the entrance of Bristol Harbor.

Closing work at Bristol on the 5th of July, the party moved to Wickford, Rhode Island, on the western side of Naraganset Bay, and continued the survey of the shore southward from Quonset Point, (Sketch No. 3.) Sub-Assistant H. G. Ogden, having reported on the 19th, commenced work there with a detached party, and extended the survey to Bissel's Cove. He then took up the survey of the northern end of Canonicut Island, from the limits of Mr. Harrison's previous topography, which had included the middle part of the island from shore to shore, and the outline of the island. Subsequently the details of the south end of Canonicut Island were completed. Meanwhile Assistant Harrison continued work with his party in the vicinity of Wickford, and after being joined there by Mr. Ogden the survey of the western shore of the bay was prosecuted until the end of November.

The country surveyed presents every variety of topographical feature found in this section. In some parts, as at the south end of Canonicut Island, the contouring was very intricate.

The statistics furnished as the results of the season's work are as follows:

Shore line surveyed	69 miles.
Roads	92 "
Creeks and ponds	64 "
Area of topography, (square miles)	33 "

Before joining the party of Mr. Harrison, Sub-Assistant Ogden had been employed in Section II, and earlier in Section V. Arrangements to work jointly in Section IV were in progress when the call was received for a detail to accompany the naval exploring expedition, which is now fitting out to search for the route of an interoceanic ship canal across the Isthmus of Darien. Sub-Assistant Ogden has been designated as one of the surveying party which will attend the expedition.

Tidal Observations.—At the new tidal station on one of the Fox Islands in Penobscot Bay, preparations have been made for recording the tides with a self-registering gauge, where the depth will be five or six feet deep at low water. A wharf has been extended out, supported by two strong piers, and a tide-gauge of improved construction is nearly completed in the workshop of the Coast Survey, to be set in place by Captain A. C. Mitchell. The position being favorable, every effort will be made to secure a good series of tidal observations at this station, and to overcome, as far as possible, the difficulties experienced in cold latitudes by freezing, the continuity of observations having been in that way frequently interrupted.

The self-registering tide-gauge at the Boston Navy Yard is still in charge of Mr. H. Howland, who has kept up the series well, except in winter, when it was often stopped by ice. Many tides have thus been lost. The series of meteorological observations is continued at that station, as also experimental observations with the new devices proposed to resist the effects of freezing.

Between these and other permanent stations short series of tidal observations are made, as

usual, by the hydrographic parties, for use in reducing soundings previous to marking them upon the charts.

Views for Charts.—As adjuncts which have in many instances been of great value to the mariner, additional views have been provided for the charts of harbor entrances between Boston and Point Judith. The following were drawn in the latter part of the present season by Mr. William B. McMurtrie, and will be engraved as soon as practicable: Boston Harbor Entrance, south channel; Salem Harbor Entrance. From the sailing course in Nantucket Sound the following were drawn, representing, severally, the appearance of the approaches to Monomoy Point Light and vicinity: Hyannis Harbor, Edgartown Harbor, Holmes's Hole, and Wood's Hole. From the sailing course in Martha's Vineyard Sound Tarpaulin Cove was drawn, and, from the approaches, the west entrance to the sound. Further westward Mr. McMurtrie made drawings of Buzzard's Bay, of New Bedford and vicinity, Mattapoisett, Sippican, Wareham and vicinity, including Bird Island and Winn's Neck Light-houses, Newport, Rhode Island, the entrance to Naraganset Bay, and a separate view of the vicinity of the light-house at Point Judith.

SECTION II.

ATLANTIC COAST, AND SEAPORTS OF CONNECTICUT, NEW YORK, NEW JERSEY, PENNSYLVANIA, AND DELAWARE, INCLUDING BAYS AND RIVERS. (SKETCHES NOS. 4 AND 5.)

Navy Yard Site, New London, Connecticut.—The survey of a site for a navy yard near New London for the Navy Department was prosecuted, under the general charge of Assistant H. L. Whiting, during parts of the months of May and June.

This work required the revival of the local triangulation and the determination of new points as a basis for the desired topography and hydrography.

The triangulation was made by Assistant Charles Hosmer, and although not extending over a large area, complex and difficult details were involved. The results were such as would meet all possible requirements in accuracy.

The topography, by Sub-Assistant H. G. Ogden, consisted of an elaborate survey of the grounds of the proposed navy yard, which extend about a mile along the river side. The topographical features were mapped on the large field scale of $\frac{1}{1200}$, and show the results of a series of lines of level in squares of one hundred feet, covering the whole map. Horizontal planes for each six feet of elevation were also determined by the level throughout the ground of the survey.

The hydrography was executed by Assistant Charles Junken, on the scale of the plane-table survey. Soundings were carried across the bed of the river in lines continuous from the series of stations used by the topographer in determining the level. These, as before stated, were one hundred feet apart. Lines of soundings to intersect were then run at distances of one hundred and fifty feet from each other, their direction being controlled by signals, stakes, and buoys, determined in position by means of the plane-table. The channel and river bed within the limits of the ground surveyed were thus developed with great accuracy.

The parties employed at New London had been previously on duty in Section V, and subsequently were engaged in service of which mention has been made under the head of Section I.

Early in October three maps on the large scale of the survey were transmitted to the Navy Department, showing the navy yard site at New London. These are marked with longitudinal and cross sections of the surface contour, and comprise all the data needed in advance of preparing the site for its proposed use.

New York Harbor.—The increase in the commerce and population of the cities situated upon New York Harbor has taxed to the utmost the natural facilities of the neighborhood, and it has become evident to merchants and others that new resources must be sought for future expansion.

The insular position of Manhattan Island, with its bold water-fronts upon the Hudson and East Rivers, rendered it peculiarly favorable for the accommodation of a commercial people for many years, and the proximity of favorable sites for business places and dwellings on the Brooklyn and Jersey City shores relieved for a long time the overwhelming population and business of the central city. But the time has come when the narrow avenue to the sound is overcrowded with vessels, when the ferries fail to supply adequate accommodation for transit, and when the

distances from centres of business to the homes of the merchants have become inconvenient with the present means of transportation. The docks and wharves, thus far of the simplest and most economical description, no longer meet all the wants of the shipping, and the contest for suitable berths has become a burden upon trade. Many citizens of foresight and public spirit in each of the three cities have for years been impressed with the necessity for providing against these increasing difficulties; but the problem is so vast, and the interests so varied and apparently incompatible, that no solution has yet been offered which gives satisfaction to all.

In the early part of the present year George W. Dow, esq., a merchant doing business in New York, laid before the Chamber of Commerce a plan for docks and causeways in the East River, which he conceived would at once supply the wants of shipping and the means of transit between New York and Brooklyn, as well as furnish a remedy for the injurious character of the strong currents which the present open passage between the harbor and the sound admits. The Chamber, at his suggestion, referred the matter—so far as it involved physical effects upon the harbor—to the Superintendent of the Coast Survey, by the following resolution:

Resolution of Chamber of Commerce passed March 4, 1869.—Whereas there is an apparent change going on in the formation of the harbor of New York and its entrance, which, if not soon attented to and corrected, threatens to be productive of very great injury to its commerce, even to the closing of the Sandy Hook Channel for large vessels, and the making of the Hell Gate Channel deeper, with swifter outward current, and even more difficult to stem or overcome, and more dangerous than at present, and, in fact, making this channel the main outlet for the waters of the ocean flood tides and the North River; therefore,

Resolved, That the attention of the Superintendent of the United States Coast Survey, at Washington, be called to this subject with a request that he will give it his early and serious consideration, and cause such examinations and resurveys to be made as the case may require, and also suggest such corrective measures as may seem best to prevent the threatened evils to this harbor.

In response to this resolution I asked for a committee of conference, and the Chamber of Commerce took action upon my request as follows:

Resolutions of April 14, 1869.—Whereas Professor Benjamin Peirce, Superintendent of the United States Coast Survey, to whom was referred the resolution of this chamber passed on the 4th ultimo, in relation to tides and currents of New York Harbor, having expressed by letter of 7th instant a desire for a committee of conference to meet him and his associates, Captain C. P. Patterson and Assistant Henry Mitchell, to consider the subject of said resolution; therefore,

Resolved, That a committee of three be appointed for that purpose.

Resolved, That the secretary of this Chamber communicate this resolution with the names of the committee to Professor Peirce, and inform him that the committee will meet him and his associates, in accordance with his wishes, either at the rooms of this Chamber or at such other place as he may prefer, leaving the day and hour to his discretion.

The committeee appointed under the above resolution consisted of George W. Dow, esq., George W. Blunt, esq., and R. W. Weston, esq.

Our first meeting was held in New York, upon the 23d day of April, 1869, and opened by Mr. Dow, with a full exposition of his plan and his views of its bearing upon the conservation of the harbor.

Captain Patterson, hydrographic inspector, and Mr. Mitchell, who has in charge the physical hydrography of the survey, stated that the apprehensions reflected in the preamble of the resolution of March 4 were not, as far as they were advised, well founded; that the repeated sounding of the Coast Survey did not show any decline in the channel depths over the bar, and that, except the changes in the immediate neighborhood of Sandy Hook, no injurious tendencies appeared in the lower harbor.

Mr. Dow hastened to assure us that he was not tenacious of his plan, but presented it as a basis for our inquiries, which he hoped might lead to a solution of the much-vexed questions of dock accommodation and transit between the two cities, with an improvement to the harbor generally, or at least with no injury to it in any direction.

Upon this liberal footing I expressed my willingness to institute inquiries as far as the data in our possession would allow, and stated that if these data were inadequate I should feel disposed

to ask Congress to appropriate funds for further field surveys, because I considered the problem presented one of national interest, whatever shape it might ultimately take. The East River is not simply a portion of New York Harbor; it is also a commercial highway between New England and the cities of the Hudson, and the west.

The Coast Survey was already in possession of a large number of tidal observations made in New York through a long term of years, and from these I made a mathematical computation of the effects upon the relative inflow and outflow that would follow the closing of the East River entrance by the plan proposed. This computation showed that a large decrease of the scouring power through the main channel would be consequent upon the loss of the East River, which is strictly in accordance with the sagacious inferences of Mr. Mitchell. My computation assumed, however, that the waters were of the same uniform density throughout, and the result which I reached must be modified in its application to the case by those of Mr. Mitchell's physical survey, undertaken and partly executed in the years 1857–'58. Mr. Mitchell's inductions from actual gaugings of the streams have led him to the most important discovery that by reason of the difference in the specific weights of the river waters and the sea, the former plays but a subordinate part in the scour of the channels; and he argues from instances of tideless rivers, like the Nile and the Danube, that the Hudson, unassisted by the tidal flowage, could not preserve the present depth upon the bar of New York. In the course of his observations he discovered that in the dry season the bottom of the main channel of the harbor, in the pathway of the Hudson, is traversed by a northwardly current, which at times is constant throughout the day. The head of the river at such times is not sufficient to balance the greater weight of the sea water, so that although the higher fresh water overflows into the sea, the salt water of the ocean flows in below to restore the equilibrium. Mr. Mitchell also pointed out the curious fact that an increase of the river outflow during his survey did not increase, but really diminished the scour, because as the flood tidal current was prevented by this outflow from carrying the sea water as high up the river as before, the waters on reaching the harbor were less mixed with those from the sea, and being lighter took a more superficial course. His observations were made at all depths, so that his statements rested upon absolute facts. He also agreed with me in the opinion that observations confined to dry seasons of the year may not represent the average conditions, and that the results from these would be greatly modified if inquiries were to be conducted through periods of freshets. Mr. Mitchell showed, furthermore, that the sound entrance permitted a grand tidal circulation through the harbor which was felt upon the bar; that all the tide waters that escape to the sound, and all the waters that pass in the opposite direction, from the sound to the harbor, increase the flowage over the bar by the same amount—an amount actually stated by him from careful gaugings. Nor was this point the result of any recent review of his observations, but really one of the earliest facts that he had reached. In his paper upon Hell Gate, to be found in the annual report of 1867, he had spoken of the circulation induced by the coexistence of two outlets as the "*life blood of New York Harbor.*" Again, it appeared from general groupings of his observations, that, independently of the daily tides, a circulation through the harbor exists between the sea and the ocean, due to the unequal effects of the moon's attraction and winds. He is inclined to think the winds play a prominent part in this circulation, since upon the shallow waters of the sound, those from the eastward, have a much greater effect in piling up the waters to leeward than they have upon the open coast, so that the flow that they would cause would be predominant in one direction, *i. e.*, southward through the harbor, and seaward over the bar.

The cutting off of the East River would also tend to diminish the flow of salt water into the harbor, so that the waters of the harbor would become fresher, and therefore more liable to the formation of ice. The freshening of the harbor would moreover increase the excess of the specific gravity of the sea water and strengthen the inward undercurrent.

These suggestions must not be regarded as final conclusions. They present at the outset a strong array of facts in opposition to the proposed dams. But if they are sustained by a thorough investigation, there will be no undue effort to force the construction of the dams to the injury of the harbor. The construction has been proposed as a great public benefit, defended with the utmost ability and candor, and should not be rejected without a full examination of all the phenomena of the case. Under these impressions I addressed to the committee the following letter:

"November 25, 1869.

"To the Committee of the Chamber of Commerce *of New York City:*

"The inestimable importance to our country of the harbor of New York needs no demonstration. A large proportion of the commerce of our Atlantic coast, foreign or domestic, passes through this port, so that every citizen of the United States has a direct interest in whatever way it may be benefited or injured. There are few questions, therefore, which demand more serious consideration than its preservation. It is the harbor which constitutes New York. It is the harbor, with its extraordinary position, its unusual capacity, and its special convenience of access, which has brought together such an accumulation of men, treasure, and trade. Whatever injury it may suffer is felt throughout this immense organization of which it is the center, and is a blow at the body of the national wealth of America.

"But this great combination of men and of wealth needs space in which to develop itself. There must be residences for all its members within reasonable distance of the business of the port. Hence it is a question of real interest to commerce, superior to all private speculation, and worthy of the attention of the greatest merchants, how can all the land within the proper distance be rendered available to the necessities of trade? No trivial obstacles nor unreasonable apprehensions should be permitted to embarrass the inquiry; but, upon the other hand, it would be a most unjustifiable breach of trust to sanction any operation which would endanger the welfare of the harbor.

"I gladly bear testimony to the candor and frankness with which the propositions have been presented for enlarging the territorial accommodations of New York, and the readiness and fullness with which the paramount importance of the harbor has been recognized.

"Within four miles of the City Hall of New York there is at least as much land, in Brooklyn, as in New York itself. The passage of the East River by the ferry is always annoying, and sometimes seems to be dangerous. The consequence of the more difficult access is, that few of the residences in Brooklyn are more than three miles from the City Hall in an air line, while many of those in New York are more than five miles distant.

"It has been proposed to construct a bridge over the East River, so high that all navigation could pass under it; and it has also been proposed to tunnel beneath the river. The objections to both of these enterprises have been so great as hitherto to prevent their adoption. But the plan which is now submitted for connecting Brooklyn with New York is by dams which shall entirely cut off the flow of East River. The arguments in its favor have been presented by Mr. Dow with exceeding ability, and an ingenious and imposing array of facts. I have entered upon their discussion with Captain Patterson, the hydrographic inspector of the Coast Survey, and Mr. Mitchell, who has the charge of physical hydrography in the survey. Assistant Mitchell has instituted a series of preliminary observations upon the tidal currents of the harbor, and has derived, among other results of the highest significance, a discovery of inestimable importance in reference to all inquiries of this nature. He has ascertained that the currents at the bottom of the deep channels are very seriously dependent upon the difference between the density of the sea water and that of the water of the harbor. The first impression made upon me by these investigations and discussions is quite unfavorable to the project of the dam. I think that various dangers are imminent upon its completion, and in our last meeting I verbally expressed to you my fears. But I think you agreed with me that the matter was not yet ripe for public discussion, and that there were too many doubtful points, to be decided by careful observation, before a final conclusion could be reached. It is evident that there should be a complete and exhaustive investigation of the currents of the harbor in every stage. Such an inquiry is beyond the means at my disposal in the present restricted state of the appropriations for the Coast Survey. But it is so essential to the commerce of the country that I must believe the next Congress will provide for it, and I am confident that yourselves and all merchants will throw the weight of your influence in favor of its accomplishment. It must, however, take some time to complete the investigation, however adequate may be the appropriation, for it must extend over all seasons of the year, and for several successive years, and when the survey is completed and the facts collected it will require many days or months of severe thought to organize them into a true theory and extract the truth which is in them. We must suffer the delay with what patience we can. We perceive how finite we are when

we have to consider an enterprise which involves all the future. Even in the next generation the commerce of New York will be, probably, tenfold what it is now. There will be ten times the tonnage of shipping to be provided for, and three times as large a population to live and have their residences. The event which would be inconvenience to us would be disaster to them. For their sakes we cannot proceed too cautiously. I trust, therefore, that after reporting to the Chamber of Commerce our present state of progress in the inquiries submitted, you will find no difficulty in persuading them to retain the matter in our hands until definite conclusions can be legitimately reached."

At our last meeting, held November 24, we agreed to postpone the question till further data should be collected, and the Chamber of Commerce at a subsequent meeting, December 2, passed the following resolutions:

Resolutions of the Chamber of Commerce of New York, adopted December 2, 1869.

Resolved, That the thanks of this chamber be tendered to Professor Peirce, Superintendent of the United States Coast Survey, and to his associates, Captain C. P. Patterson and Henry Mitchell, for their intelligent and careful attention to its resolution of the fourth day of last March, and for the cautious and able manner in which they have thus far handled a subject of the highest importance to our harbor and its commerce.

Resolved, That this chamber approves of the suggestion of Professor Peirce for an appropriation from the Congress of the United States in order to make further inquiries and investigations into the condition of the tidal and river waters of New York Harbor, and urgently recommends such appropriation.

Resolved, That the committee already appointed to confer with Professor Peirce and his associates in this matter be retained by the chamber, in accordance with his request, for further interviews and communications with them.

Hydrography of Sandy Hook Channels, New York.—For such special uses as might be of importance to the United States engineer officer, General Newton, at Sandy Hook, Assistant F. F. Nes commenced soundings and current observations in that vicinity on the 29th of June. Tides were observed with a gauge stationed at the government wharf from the 27th of June till the 12th of July.

Marked changes were noticed on Flynn's Knoll, as having taken place since soundings were previously made in that vicinity. The point making out from East Beacon (Sandy Hook) has also changed, as may be inferred from the record of soundings. The chart of Assistant Nes includes soundings made over the wreck of the steamer *Scotland.* The currents in the vicinity of Sandy Hook were observed at four stations. In general statistics the results of this examination are as follows:

Miles run in sounding	75
Angles measured	560
Number of soundings	2,068

Additional work done by Assistant Nes in this section will be stated under the next head.

Hydrography of Wallabout Channel, New York Harbor.—This work, asked for as a basis for estimates in regard to deepening the channel, was taken up by Assistant Nes on the 30th of August. The required scale of the chart is quite large, ($\frac{1}{1250}$,) and involved the necessity for close determinations, which were found difficult in consequence of the disturbance or loss of old triangulation points by subsequent changes and improvements in the vicinity of the navy yard. Mr. Nes established a base line on the ordnance dock, and from its ends observed on known points in New York and Brooklyn, and thus determined the connection of his work with the hydrography of East River. For the soundings he was furnished with a boat's crew from the receiving ship Vermont. The work was closed on the 16th of October, and is represented by the following statistics:

Miles run in sounding	22
Angles measured	1,896
Number of soundings	2,083

A chart of the Wallabout Channel has been completed and furnished to the authorities of the New York Navy Yard.

Hydrographic service performed by Assistant Nes in the early part of the surveying year will be noticed under the head of Section IV.

Triangulation and azimuth, coast of New Jersey.—In my last report reference was made to the connection of the secondary triangulation along the coast of New Jersey with the primary work in the vicinity of New York, and to the suspension of the final details on account of the illness of the assistant assigned to that duty. For completing the operation, and for the more extended one of verifying the coast series from Sandy Hook to Absecom Inlet, Assistant A. T. Mosman was assigned early in May, and commenced work in the field towards the middle of that month. By the 16th of July the angles of the first quadrilateral south of the line *Chapel Hill*, *Mount Mitchell*, were observed, a partial reconnaissance was made for the improvement of the triangulation between Long Branch and Squam; and the astronomical azimuths of two lines were determined, one at the northern and the other at the southern extremity of the triangulation. In this work seven signals were erected and four stations (see sketch No. 5) were used for the measurement of horizontal angles. The azimuths of the two lines from Chapel Hill and Leeds Point were determined by 104 observations on three stars, near elongation.

Sub-Assistant F. Blake, jr., was attached to this party. When the operations were closed, Assistant Mosman joined the party of Assistant Cutts, at Bristol, Tennessee, and Mr. Blake reported for duty to Assistant Dean, as will be mentioned under the head of Section VII. Both had been previously engaged in Section I, and Mr. Mosman subsequently at another station in Section IV.

Topography of Absecom Inlet and vicinity, New Jersey.—The ground surveyed by the party of Assistant C. M. Bache includes Absecom Inlet and the coast line six miles below the entrance. The fast land along the beach is comprised in a strip somewhat less than a mile in width, inside of which is the great body of marsh peculiar to the seaboard of New Jersey. Besides the main coast road, of which a stretch of about nine miles is represented on the plane-table sheets, some slight elevations were found, the contour lines showing in some places a height of thirty feet. Field-work was commenced on the 12th of July, and was continued until the 11th of November.

Sub-assistant H. W. Bache joined the topographical party after the middle of August, and assisted in the plane-table work.

Atlantic City is included within the limits of this survey, and also the town of Absecom. The general statistics of the work are as follows:

Coast-line	9 miles.
Shore-line, bays, creeks, &c	197 "
Outline of marsh	25 "
Roads	43 "
Area of topography, (square miles)	33 "

After inking and turning in the plane-table sheets Assistant Bache made preparation to resume topographical service in Section V.

Preservation of primary stations.—The inspection of station marks of the primary triangulation, and the adoption of such means as were found to be necessary for their preservation, have been continued by Assistant John Farley. During the past season he has visited fifteen points, and these, with the number examined in 1868, complete the entire series in this section, extending from the western end of the base-line on Long Island, across New Jersey and Delaware Bay, to station *Back*, in the State of Delaware.

Mr. Farley reports that every precaution was taken that the circumstances of the ground would admit to insure the identification of the points hereafter, by numerous measurements, ranges, and references, and by full descriptions, vertical and horizontal projections, and finally by illustrative sketches appended to his concluding report.

Survey of Rondout, New York.—Having completed the survey of the lower part of Rondout Creek, and of the adjacent shores of Hudson River, in November, 1868, Assistant F. H. Gerdes proceeded to draw and ink the two large topographical sheets which resulted from his work in the

field. The survey is represented on an ample scale, and will suffice for any improvement projected for the navigation between New York City and Rondout.

In the spring of the present year Mr. Gerdes plotted and drew a hydrographic sheet to represent soundings which he had made in the previous autumn in New York Harbor; and after making determinations on the ground, made sketches of the new quarantine islands and buildings on the west banks, in lower New York Bay. His subsequent service will be referred to under the head of Section III.

Tidal observations.—The series of tidal observations in New York Harbor has been continued as usual, by Mr. R. T. Bassett, with the self-registering gauge on Governor's Island, and with the box-gauge at the dock of the Hamilton Avenue ferry, in Brooklyn. In a few years more this series will be sufficiently extended for general discussion. Already it has furnished data for use in the construction of many important and costly works, both public and private, in the harbor and its connected waters. The records have also a special bearing on the investigation of the changes which are going on in New York Harbor, or which may be caused by removing the impediments to navigation at Hell Gate.

SECTION III.

ATLANTIC COAST AND BAYS OF MARYLAND AND VIRGINIA, INCLUDING SEAPORTS AND RIVERS.

Azimuth at Seaton Station, Washington, D. C.—The observations to determine the direction of the lines of triangulation near Washington City were made by Assistant C. O. Boutelle with the thirty-inch theodolite, between the 9th of December and the 7th of January. Azimuth observations were made upon δ Ursæ Minoris at its western elongation, and upon Polaris at different times between three hours after culmination, and the western elongation of that star. Angular measurements were made between the star, observed alternately direct, and also as reflected in mercury and the reference mark. The local time was obtained from the Naval Observatory through the courtesy of Commodore B. F. Sands, the superintendent, and Professor Simon Newcomb, United States Navy.

Assistant Boutelle prefers the observations on Polaris at the times referred to, as most likely to give accurate results, for the reason that greater precision in pointing can be attained when the star is moving in azimuth sufficiently fast to make its own contact with the cross hairs visible, after they have been brought near to it by the tangent screw.

For the azimuth 610 observations were recorded of the stars and reference mark. The determination was transferred to the north meridian mark heretofore used in all the longitude observations, and to Hill Station, the only triangulation point now visible from Seaton, by 210 measurements of horizontal angles. The resulting values of the angle between the meridian mark and Hill, as measured in 1850 and in 1869, agreed within a quantity equal to about three-tenths of an inch at the distance of two miles, at which the meridian mark was situated from the observer.

As the streets in that part of the city in which Seaton station is may soon be graded, Mr. Boutelle took the precaution to mark the point permanently by a copper bolt set in the brick foundation of the transit piers, and by other means detailed in his report.

The entire work was reduced and the computations, together with the records, original and duplicate, were turned in at the office before the close of January.

Primary triangulation.—Assistant Boutelle returned from duty on the coast of South Carolina in the latter part of May, and immediately resumed field-work on the primary triangulation near Washington City. Additional stations were selected, and signals were erected at Maryland Heights, Bull Run Mountain, and Mount Marshall, near Front Royal, Virginia. These points command views over the valley of the Shenandoah and would serve for determining positions on the ranges of mountains west of it, though selected mainly with reference to geodetic connection with points eastward of the valley. Their determination will furnish data for local surveys of this quarter much more accurate than any that now exist.

In July Mr. Boutelle resumed the measurement of horizontal angles at Stabler Station, in

Montgomery County, Maryland. The season was made very unfavorable by the drought which prevailed throughout the Middle States during the summer. Heat radiated from the ground caused a constant disturbance of the air through which the lines of sight passed, and thus the distant signals could not be observed as satisfactorily within the period usual for occupying a primary station. As at station Hill, which was occupied last season, the thirty-inch theodolite was mounted at Stabler upon a tripod fifty-five feet high. Observations were, however, completed at that station in the latter part of August, the records showing six hundred and sixty-eight measurements of horizontal angles upon eleven stations, and one hundred and fifty-three measurements of vertical angles upon ten stations. Before closing work at Stabler, Assistant Boutelle determined in the usual way the magnetic declination and intensity.

In September the party was transferred to Peach Grove Station, in Fairfax County, Virginia, where an observing tripod was erected forty-five feet high. Observations were continued at such favorable intervals as occurred in September, but in the following month the weather became exceedingly inclement before the intended measurements could be completed at that station. I personally inspected the operations of this party in the field. The obstacles which tend to limit the scope of a work so laborious in its details, and which for that reason should be made to command as much ground as possible, have been met with great judgment in the reconnaissance by Assistant Boutelle. Long lines of sight have been obtained by elevating the theodolite at three points for the determination of distant positions; resort to that expedient will not be required in extending the triangulation to the southward. Mr. James T. Boutelle served as temporary aid in the triangulation party.

Magnetic observations at Washington, D. C.—The series of monthly observations commenced in January, 1867, and continued for two years and a half without interruption, was undertaken with a view of determining with special accuracy the secular change of the magnetic declination, dip, and intensity. Assistant Charles A. Schott made the observations on three consecutive days at the middle of each month, at the Coast Survey magnetic station on Capitol Hill. The declinometer used was of the form devised by Lamont, supplied with very small magnets. The dip circle had two position needles, and each was used in three positions of the axle. Mr. Schott determined the instrumental constants with great care, and the measure and application of the earth's induction was here for the first time introduced in the Coast Survey practice of observing. The method employed is fully explained in the report of Assistant Schott, which is given in the Appendix, No. 9. Coefficients for the deflection were determined from observations extending over one year, and the values were corrected for the effect of induction.

The paper in the Appendix contains an abstract of the monthly values found for the declination, the dip, and the horizontal intensity between the beginning of the year 1867 and the month of June in 1869, and the annual change of each of the elements. The epochs of eastern and western magnetic elongation are given for the declination. The effect of the secular change Mr. Schott finds to be an annual increase of nearly three minutes in western declination; an annual decrease of four minutes and three-quarters in the dip; and an annual increase of nearly four thousandths of the horizonal force. His report notices specially the secular variation, which changed a few years ago from annual decrease of the horizontal intensity to an annual increase, and the change of an opposite character in the dip. The paper concludes with a valuable transcript of all known or accessible magnetic measurements made in the District of Columbia, the earliest dating back to the year 1792.

The yearly changes having been deduced from the series of monthly observations, it is proposed to make, hereafter, annual determinations of the magnetic conditions at the Coast Survey station on Capitol Hill.

Under the head of Section VIII notice will be made of special observations conducted by Assistant Schott on the occasion of the total eclipse of the sun which occurred in August of the present year.

Base-line near Craney Island, Virginia.—The primary triangulation along the sea-board of this section having been completed, it was deemed advisable to close and verify it by the measurement of a base at the foot of the Chesapeake. Assistant Richard D. Cutts, who had already pushed the work southward of Cape Henry, as will be detailed hereafter, was accordingly joined by Assistant

R. E. Halter, for the purpose of making a thorough reconnaissance of the shores in the vicinity of the entrance to the bay. In conformity with his instructions Mr. Halter commenced a careful examination on the 20th of July, and traversed the bay shores from Back River light-house to Fortress Monroe; then Smith's Island, on which Cape Charles light-house is situated; also the region between Tanner's Creek and Sewall's Point, and finally the river shore from Craney Island westward. After a critical comparison of the advantages and disadvantages of each locality, Assistant Cutts selected the site last mentioned. The position was the most favorable one for measurement; it could be readily connected with the main triangulation of Chesapeake Bay, and, as it overlooks Hampton Roads and the channel to Norfolk, the site is conveniently situated for any further surveys which may hereafter become necessary in that important quarter.

The party was organized for active duty on the 19th of August. After the detail of Sub-Assistants Ferguson and Perkins, Assistant Halter proceeded to open, clear, and grade the line, and to make the preliminary measurement with an iron wire sixty meters in length. The final measurement was begun on the 20th of September, with the contact slide apparatus, and was finished at the end of that month. According to the preliminary computation of Mr. Halter, this base-line is 5,136.6 meters in length. Its ends are on firm and secure ground, and were marked by blocks of granite resting on brick foundations laid in hydraulic cement, and also by iron screw-piles. After the measurement the apparatus was sent to the office for the usual re-comparison of the rods with the standard six-meter bar No. 2.

At the end of October Assistant Halter had made good progress in the measurement of horizontal angles according to the scheme laid out for connecting the base with the primary triangulation. The operations of the party were inspected by Assistant Cutts.

Assistant Halter had been previously engaged in duty in Section V. He is now making arrangements for commencing the hydrographic survey of the James River in this section.

Hydrography of the Chesapeake estuaries.—The large chart of Chesapeake Bay, issued several years since, contained the sounding of the body of the bay and all the information needed for general navigation, and for entering the principal rivers and branches of the bay. The lesser branches then left outstanding have since been defined, and in my report of last year mention was made of the work of this kind done on the estuaries of the lower part of the bay. In continuation of this service the party of Assistant J. W. Donn remained in the field from the 1st of November, 1868, until the end of June of the present year. Before sounding Piankatank River and Milford Haven, Mr. Donn traced the shore-lines with a plane-table. Several estuaries near Urbana, on the Rappahannock, were then surveyed, and the more extensive branches of the lower part of the Potomac River, as also the Chesapeake estuaries between those rivers. In like manner all the branches of the Patapsco River were sounded, and the results will be added to the chart already published. Assistant Donn was aided in the hydrographic work by Mr. C. P. Dillaway. The tides were observed as usual to make the soundings conformable to those which appear on the engraved sheets of the bay. A synopsis of statistics is thus given in the report for the season:

Shore-line traced	157½ miles.
Miles run in sounding	513
Angles measured	2,152
Number of soundings	20,725

The schooner Bowditch was used for transportation by this party. After the close of the work Mr. Donn proceed to Portland and engaged in service which has been mentioned under the head of Section I.

Progress Sketch No. 6 shows the work added this year to the survey on the Chesapeake by the two parties detailed for service. Assistant Donn has been directed to resume work in this section on the sea-coast above Cape Charles.

The party of Sub-Assistant W. W. Harding, with the schooner Hassler, was employed during the greater part of the working season on the eastern side of Chesapeake Bay. On the 15th of and the hydrography of that vicinity was completed by the 13th of January. Work in the im-December, 1868, soundings were commenced in the Little Annemessex River, (see Sketch No. 6,) mediate vicinity, on the eastern shore of Virginia, was taken up in a few days after, and was closed

on the 12th of April. The party then sounded in the vicinity of Smith's Island, Fox Island, and Tangier Island, and completed work in that quarter by the end of May.

Beginning on the 8th of June, Mr. Harding and his aid, Mr. A. F. Pearl, run the shore-line of Pocomoke River, and sounded out that branch of Chesapeake Bay by the 8th of July.

The topography and hydrography of the estuaries of the Chesapeake immediately north of Cape Charles were completed by the party in the Hassler between the end of July and the beginning of October.

In these various patches of work, eighty-five signals were erected by the hydrographic party. The work done essentially completes the chart of Chesapeake Bay, which, as before stated, was first issued without representing the numerous small branches that indent its shores. An aggregate of the statistics of work done by the party in the schooner Hassler is appended:

Shore-line surveyed, (miles)	22
Miles run in sounding	777
Angles measured	2,861
Number of soundings	59,132

Light-house positions in Chesapeake Bay.—After determining the position of the two new range lights for the Brewerton channel of the Patapsco River, Assistant F. H. Gerdes made a small triangulation in the vicinity of Fort McHenry, and determined the position occupied by the flag, staff of that work. Early in August he took up the verification of the position of the light-houses and buoys that are marked on the charts of the Chesapeake and its tributaries. This service was completed by the middle of November, and has included all parts of the bay from Havre de Grace to Norfolk and Cherrystone. Sailing marks in Bush River were reviewed, and those in the Severn, in West River, South River, the Patuxent, the Potomac to a distance of fifty miles from its entrance, the Rappahannock to a distance of forty-five miles, York River for forty miles, and Hampton Roads; on the eastern side of the bay, Chester River, East Bay, Choptank River, Tangier and Pocomoke Sounds, and the smaller inlets between them and Cape Charles. The positions of new light-houses, not yet on the charts, were ascertained and plotted. All buoys now marked on the maps were determined in their present places, and the differences were noted for corresponding alterations on the engraved charts. The positions of new buoys were found by observations with the theodolite, and have been recorded for future chart publications. In the aggregate, more than a hundred points were determined by angular measurements in the course of the season. The concluding report, by Assistant Gerdes, with recommendations of the changes suggested by his research with regard to the lights and buoys of the Chesapeake, as a system of aids for navigation, has been transmitted for the information of the Light-house Board.

Mr. C. P. Dillaway aided Mr. Gerdes in the field, and in bringing up the large amount of office work resulting from his observations.

Tidal observations.—At Old Point Comfort, Virginia, the series of observations with a self-registering tide-gauge, which has been continued for some years, is still in the care of Mr. E. F. Krebs, whose labors have been very satisfactory. This is one of our longest series, and will soon be fit for discussions relating to the effects of the attraction of the heavenly bodies on the waters of the earth. Many short series have been made at points on the Chesapeake and in its estuaries, the hydrography of which has recently been completed.

SECTION IV.

ATLANTIC COAST AND SOUNDS OF NORTH CAROLINA, INCLUDING SEAPORTS AND RIVERS. (SKETCH No. 7.)

Base-line on Back Bay, Virginia.—In my report for last year mention was made of the preparations for measuring a line to connect the triangulation of Chesapeake Bay with the main series stretching to the northward from the base-line on Bodies Island, on the coast of North Carolina. At the same time a scheme of triangulation had been laid out to extend to the southward of the new base. During the month of April the six-meter rods of the base apparatus were compared with the standard at the office, the trestles were put in order, and all the other needful preliminaries were completed for performing the work laid out in the preceding scheme.

On the 4th of May Assistant Richard D. Cutts, accompanied by Sub-Assistants C. Ferguson and F. W. Perkins, reached the ocean beach below Cape Henry, where the direct measurement of the coast mentioned in my report for 1867 was discontinued. The terminus of the nine-mile line was found in the condition in which it was left on closing work in that year. Commencing at that point, a base made up of two lines slightly differing in direction, and extending from Deep Ditch to Little Island, (Sketch No. 7,) was laid off along the ocean beach. The division into two parts was rendered necessary by changes in the high-water line, and to avoid wrecks and sand-knolls. After the alignment of the courses, and their preliminary measurement with a sixty-meter iron wire, the final measurement began on the 15th, and, though interrupted by storms and high tides, was completed on the 25th of May. Nine hundred and ninety-two bar measurements were made, giving an aggregate length for the two lines of 5,953.02 meters. The computed length of a straight line, which would join the ends of the base, is 5,952.6 meters.

In this, as in the measurements made in 1867, the rods were compared with the standard at Washington, both before and after they were used in the field, and the mean of the two comparisons was adopted as the length of the respective rods.

Triangulation of the coast of Virginia below Cape Henry.—On the 31st of May Assistant Cutts, having completed the work mentioned under the head immediately preceding, commenced the measurement of horizontal angles at North Base, (Sketch No. 7,) and by the 7th of July effected a complete junction with the triangulation of Currituck Sound, upon the line joining Ragged Island and North Point, one of the lines of the old triangulation. Upon comparing the results obtained respectively from the Chesapeake triangulation and the base on Bodies Island in North Carolina, by separate schemes and methods, the differences were found to be so slight as to render it unnecessary to push the verification further to the southward, as originally intended. The statistics of this triangulation are given in the following synopsis:

Signals erected	10
Stations occupied	7
Angles measured	40
Number of observations	1,600

The triangulation having been satisfactorily completed the party was discharged, and Assistant Cutts returned to Washington and made suitable arrangements for observing the solar eclipse of the 7th of August, mention of which will be made under a separate head. Sub-Assistant Ferguson was soon after assigned to duty in Section III, as was also Sub-Assistant Perkins, upon his return from duty with the astronomical party at Bristol, Tennessee.

The originals and duplicate records of observations, descriptions of stations, and plan of the triangulation made this season on the coast of Virginia have been deposited at the office in Washington.

Azimuths at Knott's Island, Virginia.—To complete and close the operations just described it was necessary that the astronomical azimuth of the line of junction should be observed, and this duty was assigned to Assistant A. T. Mosman.

In accordance with instructions, immediately after closing work under the direction of Assistant Cutts at Bristol, in this section, Mr. Mosman proceeded to Norfolk, accompanied by Sub-Assistant Perkins, and thence to the station on Knott's Island, in the northern part of Currituck Sound, in Virginia, which was reached on the 13th of August. Assistant Cutts having previously made preparations for occupying the station, the observations for time and azimuth were commenced immediately, and were completed to his satisfaction in two days. The azimuth was determined by ninety measures of the angle between Polaris, near its eastern elongation, and the mark, and the time by seventy-two double altitudes of the sun. The mark in this case was one of the signals erected and used in the main triangulation. On the 21st of August the party returned to Norfolk and was discharged. Until further orders for the field Mr. Mosman was employed in making the requisite computations of his astronomical work, and Mr. Perkins joined the party of Assistant Halter for duty, which has been noticed under the head of Section III.

Hydrography of the coast of North Carolina.—After repairs at Norfolk on the steamer Bibb, following the season of her service which will be mentioned under the head of Section VI, Acting

Master Robert Platt took up hydrographic duty to the northward of Cape Hatteras, on the coast of North Carolina. Early in August Sub-Assistant Gershom Bradford, with a light-draught schooner which was chartered for the purpose, went up the coast from Hatteras Inlet and set and determined the signals to be used in running the lines of soundings needed in the vicinity of the Wimble Shoals. Of these Acting Master Platt reports: "On and around the shoals the bottom is very uneven, varying suddenly from eight to ten fathoms, and from four to five fathoms. The least water found on the shoals is three and a half fathoms, at two places. Soundings were made very close, and will show at a glance the whole character of the Wimble Shoals. No vessel drawing more than eighteen feet should pass in less than eleven fathoms of water, either around the Wimble or around Hatteras Shoals."

In reference to the currents on this part of the Atlantic coast it is observed in the same report: "The currents on the coast of North Carolina north of Hatteras are governed by the wind, and are very strong, making heavy rips, which have every appearance of shoals to those who are not familiar with them. Sometimes the current begins to run quite strong twenty-four hours in advance of the wind at the same place. In our experience the storm, which was sure to come, always set in from the direction in which the current had started."

Loggerhead Inlet, once an opening from the Atlantic into the waters of Pamplico Sound, was found by the party to be now closed. Only two inlets at present exist on the coast of North Carolina, north of Hatteras. These are New Inlet, with four feet of water at low tide, and Oregon Inlet, with the capacity (five feet) found in the survey of 1862.

The following statistics express the hydrographic work done in the vicinity of the Wimble Shoals:

Miles run in sounding	310
Angles measured	865
Number of soundings	4,751

Mr. J. B. Adamson was attached to the party as aid. At the end of October the steamer Bibb proceeded to Norfolk to refit for service at the western end of the Florida Reef.

While on duty near Bodies Island, on the coast of North Carolina, as many as fifteen wrecks were in view at the same time from the deck of the surveying steamer. In allusion to the character of the coast there Mr. Platt says: "The land is so low at Bodies Island that it cannot be seen in the afternoon more than two miles off shore, while *Roanoke Island*, which is back of Bodies Island, is in plain sight, and readily deceives the unacquainted."

Sketch No. 7 shows the site of work referred to in this notice.

Triangulation of Pamplico Sound, North Carolina.—The triangulation of Pamplico Sound has been continued by Assistant G. A. Fairfield, and in the progress of that work special attention has been given to the connection of the base near Newbern, with coast stations in the vicinity of Ocracoke Inlet. In consequence of storms which delayed the passage of the schooner Dana from Portland, the party was unable to commence operations in this section until the 11th of February. After the determination of points between Bay River and Pamplico River, required for the topographical party of Assistant Dorr, who was to be engaged on the western shore of the sound, Mr. Fairfield erected signals at Swan Quarter, Judith, and Bay River stations, (Sketch No. 7,) and from the last mentioned he determined additional points for continuing the plane-table survey. From this time forward until the 10th of July, the progress of the triangulation was interrupted and much delayed by smoke, violent squalls, and continuous high winds. Nearly all of the most important signals were blown down, and much time was consumed in their re-erection. By the 19th of August the principal stations had been occupied, and the observations were at that date so far finished as to effect the desired junction with the previous work of triangulation that passes along the coast near Ocracoke Inlet.

The party continued in the field until the end of August. The following is the return in statistics:

Signals erected or re-established	14
Stations occupied	8
Angles measured	58
Number of observations	610

Eleven points were determined in position by the measurement of horizonal angles. Three of the stations so ascertained were the light-houses, one on the northwest point of Royal Shoal, that on the southwest point of the same shoal, and the light-house on Harbor Island.

Sub-Assistant F. W. Perkins was attached to the triangulation party until the 1st of May, when he was detailed for duty in the party of Assistant Cutts. From the 1st of May Mr. J. Hergeshcimer served as aid until the close of the season.

The following extract from the report made by Captain (now Colonel) T. J. Cram, United States Engineer Corps, who was engaged in the reconnaissance for the triangulation of Pamplico Sound at the outbreak of the recent war, explains the difficulties to be encountered in that region. Every feature of land and water and character of weather opposed to rapid progress seem to be concentrated in Pamplico Sound: "To the local difficulties cited by Major Prince, as consisting in the unrelieved curvature of the earth, the softness of the marshes, the way of living, and the weather, I must add the remoteness of settlements from the stations to be occupied, which renders it impossible to obtain help, food, water, or pilotage for an emergency; the want of sufficient depth of water to enable the vessel to approach near to the stations, and the want of firm ground on which to encamp while occupying the stations. These natural difficulties are enhanced by many inconveniences, among which are the daily, not to say hourly, liability of the vessel having to weigh anchor and beat away, in order to avoid being driven on shore."

After turning in the records and duplicate journals of the triangulation Assistant Fairfield reorganized his party, and is now ready to resume field-work in this section.

Topography of Bay River and Jones's Bay, (Pamplico Sound, North Carolina.)—In continuation of his survey of the banks of the Neuse River, Assistant F. W. Dorr resumed plane-table work at Swan Island (Sketch No. 7) in the middle of January, having previously organized a party at Newbern to work with the old steamer Hetzel, which was used as a hulk for transportation. On the 20th of May the vessel was again laid up. The interval of time was employed in the topographical survey of the branches of Pamplico Sound that lie between the Neuse and Pamlpico rivers. Mr. Dorr thus refers to the character of these estuaries: "Bay River is upward of fifteen miles long and two miles wide at the mouth, from both points of which dangerous shoals extend at least two miles into the sound. At ten miles from the entrance the river has a breadth of half a mile, and has a good beating channel, which gradually decreases in depth from three fathoms to eleven feet. But the emptying of Trent River and Chapel Creek reduces the depth to eight and a half feet in the bight known as Mason's Bay. This is the shoalest part of Bay River. Any vessel that can cross the Swash at Hatteras can be carried to the town of Jackson, and can lie alongside the wharf there.

"The second sheet takes up the shore-line to the northward of the mouth of Bay River, and after delineating Jones's Bay, carries the western shore of Pamplico Sound to the mouth of Pamplico River, including Middle Bay, Big Porpoise Bay, Little Porpoise Bay, and Mouse Harbor, and the Marsh Islands, off-shore west of the Pamplico River channel.

"Jones's Bay is upward of a mile wide at the mouth, gradually decreasing in width to a point about five miles from the entrance. For two-thirds of this distance there is a good beating channel, varying in depth from two and a half fathoms at the entrance to eight or nine feet off the mouth of Ditch Creek.

"From the mouth of Jones's Bay northward to Pamplico Point, on which there is a small light-house, all the shore is marsh, intersected by bays and bights. From Mouse Harbor a canal about half a mile in length has been cut through the marsh into Oyster Creek, a branch of Pamplico River; but this cut is available only for small boats.

"An immense shoal extends from the mouth of Pamplico River on the one side and the northern point of Jones's Bay on the other, and in its stretch of fifteen miles embraces Brant Island and its vicinity."

Mr. Joseph Hergesheimer served with this party as aid from the opening of the season until the middle of May, when he was transferred to the party of Assistant Fairfield. Sub-Assistant H. W. Bache joined Mr. Dorr's party early in February, and continued with it until the close of the working season. The following are statistics of the plane-table survey:

Shore-line of sound and branches	210 miles.
Shore-line of streams, &c	94 "
Roads	115 "
Area of topography, (square miles)	110 "

During the summmer and autumn Assistant Dorr was employed in work of which notice has been taken under the head of Section I. He is now preparing to resume the plane-table survey of Pamplico Sound, in the vicinity of Pamplico River.

Hydrograyhy of Pamplico Sound, North Carolina.—Between Pamplico Point light-house and the mouth of Neuse River the hydrography of Pamplico Sound has been prosecuted by Assistant F. F. Nes with a party in the schooner Arago, attended by a small steam launch. Some boat work is yet needed for the final completion of the chart of the lower part of the sound, but as far as now done the hydrography includes the sailing courses and soundings between Hatteras and Ocracoke Inlets respectively, and the port of Newbern on the Neuse River; and also the sailing course for vessels passing from Neuse River into Pamplico River, as will be seen by reference to the progress sketch, No. 7. The soundings made by Mr. Nes include the main approach to Neuse River, and the branches of the sound known as Bay River, Jones's Bay, and Mouse Harbor. Work was commenced on the 18th of December and closed for the season on the 2d of June. Assistant Nes was subsequently employed in Section II.

For the adjustment of soundings made in the vicinity of Neuse River entrance the tides were observed throughout the working season.

The general statistics are as follows:

Miles run in sounding	890
Angles observed	4,269
Number of soundings	56,373
Area sounded, (square miles)	151

Assistant Nes was aided in duty in this section by Messrs. L. B. Wright and G. L. Schaeffer, jr. The party is now preparing to resume work for the winter and ensuing spring.

The mainmast of the schooner Arago being much decayed, it became unserviceable after a heavy squall in April. In order to continue work Assistant Nes purchased from the owners the mast of a new schooner that had been wrecked outside of Ocracoke Inlet, and had it fitted to the Arago at Newbern.

Solar eclipse of August 7, at Bristol, Tennessee.—The most easterly station at which it was deemed advisable to observe this important eclipse was situated in the mountain region of southwestern Virginia and Tennessee. Assistant Richard D. Cutts, inspector of secondary triangulation, was charged with the duty of making the precision observations there. His party, including Assistant A. T. Mosman and Sub-Assistant F. W. Perkins, left Washington on the 24th of July, and without delay reached Bristol, Tennessee, with the requisite instruments. The geographical position of that place, according to the most reliable map, was in close vicinity to the central line of the eclipse. Preliminary observations, made soon after the arrival of the party, satisfied Assistant Cutts that the position was sufficiently near for the object in view. Bristol is on the line of the Virginia and Tennessee Railroad, and immediately on the boundary, as at present recognized, between the States of Virginia and Tennessee. A temporary observatory was erected on a hill 1,760 feet above the sea, on the north side of the State boundary, and on the 28th of July the zenith telescope and transit were mounted on their respective piers.

Assistant Mosman determined the latitude of the station by twelve pairs of stars, with a probable error of $\pm 0.''15$; and the longitude by transmitting time signals to the Naval Observatory at Washington on the nights of the 29th and 31st of July, and on that of August 7, one of the wires of the Western Union Telegraph Company having been kindly placed at the disposal of the party of Mr. Cutts.

The time was obtained with transit No. 7 on eight nights, by the transits of 74 stars; and the latitude by zenith telescope No. 2 on three nights, the number of separate results being thirty-three. The value of the micrometer screw of the zenith instrument was determined by 80 observations on Polaris at its eastern elongation.

On the afternoon of the 7th of August the weather was clear and the atmosphere unusually transparent. The times of the four contacts were carefully observed by Assistant Cutts, as also, of the immersions and emersions of each one in the four groups of spots on the sun. The protuberances or solar clouds which appeared during totality, and two long pencil-like rays where the sun disappeared, were noted, and their position angles from the vertex and north point of the sun, were plotted with as much precision as the means at the disposal of the party would permit. The eclipse at Bristol was strictly regular throughout its different phases, being, as Mr. Cutts remarks, unusually free from the phenomena caused by atmospheric irregularities. At the last contact, however, when the sun was close to the horizon, the limb of the sun at that point presented the phenomena known as "Baily's Beads."

In his report Assistant Cutts makes acknowledgment of the valuable assistance accorded to his operations by Commodore B. F. Sands, Superintendent of the Naval Observatory, and by Professor Yarnall, in the determination of the difference of longitude between Bristol and Washington.

The eclipse station being close to the State line, was connected with one of the boundary marks by a base line and small triangulation. Two points were established by observation on the present recognized boundary between the States of Virginia and Tennessee, and the latitude and longitude were carefully determined at each point. At these two points monuments will be placed by the citizens of Bristol and Goodson for future use and reference.

The detailed report of Assistant Cutts is given in the Appendix No. 8, in which will also be found the reports of assistants who observed the eclipse in Kentucky, Illinois, Iowa, and Alaska.

SECTION V.

ATLANTIC COAST AND SEA WATER CHANNELS OF SOUTH CAROLINA AND GEORGIA, INCLUDING SOUNDS, HARBORS, AND RIVERS. (SKETCH No. 8.)

Hydrography of Charleston Bar, South Carolina.—With special reference to the requirements of the light-house service, an examination has been made of the channels leading to Charleston Harbor, the object being to determine proper sites for the range lights, and other marks needed in navigation. This duty was commenced by Assistant R. E. Halter on the 28th of January, and occupied his party in the steamer Endeavor until the latter part of the following month. The service was concluded by a minute report from Mr. Halter, giving reasons for the selection of certain sites for range lights for passing safely through the main ship channel, and sites for marks needful in the safe navigation of the other channels. In general reference to the results of his examination Assistant Halter reports: "My survey shows slight changes since the survey by Assistant Boutelle, in 1866, except over the southern part of the bar, which is now deeper, and tends more to the eastward." More water was found over the south channel coming in than has been hitherto reported. Mr. Halter recommended range lights for that channel, and suggested the removal of the outer light-vessel and the buoys to positions in range with the lights of the main ship channel. Sailing directions based on the proposed changes were given in the report, and minute descriptions of the sites recommended for the consideration of the Light-house Board. These notes and others for readily identifying the marks set by Mr. Halter on Morris Island, and a chart indicating their exact positions, were transmitted for the information of the board early in March.

Assistant Halter was aided by Messrs. G. W. Bissell and W. I. Vinal. The party was subsequently engaged in similar duty at St. Andrew's Sound and at Fernandina, and also in general field-work of which notice has been taken under previous heads.

Primary triangulation between Port Royal, South Carolina, and Savannah, Georgia.—This work is about to be resumed by Assistant C. O. Boutelle. The stations are selected, and under favorable circumstances the observations needful for the geodetic connection of the astronomical station at Savannah with the primary triangulation to the northward will be made in the course of the coming winter and spring. During the present year the operations of Assistant Boutelle were confined to the opening of lines and examination of the ground to be occupied. The triangulation in this section is yet in advance of the topography and hydrography. Hence, in order to afford more scope to those branches of the work, the expense of completing the primary triangulation south-

ward to Savannah River has been deferred. The connection will be perfected in the ensuing season if practicable.

Under Section III mention has been made of the occupation of the party of Mr. Boutelle during the summer and autumn of this year.

Topography of the Romerly Marshes, Georgia.—A party in charge of Assistant Charles Hosmer, detailed for duty in this section, occupied the working time between the opening of the year and the 6th of February in a plane-table survey of the shores of Wilmington River, contiguous to Skiddaway Island, and in defining and mapping the watercourses that intersect the Romerly Marshes. Sub-Assistant H. G. Ogden was attached to the party, and two plane-tables were employed in the work. The statistics are combined with those of a more extended survey made by the same party, notice of which will be made presently under a separate head.

Topography between Ossabaw Sound and Sapelo Sound, Georgia.—The coast topography previously done between the two sounds just named extended inland to a distance sufficient for the completion of general charts, but did not include in all its course the important feature known as the Inland Passage, by which vessels may be passed in a route parallel with the coast, from sound to sound, and quite across the marine border of the State of Georgia, without any outside navigation. This important passage has now been mapped and nearly completed in soundings, from the Savannah River to the upper waters of St. Andrew's Sound. Additions to the plane-table survey were made this year by Assistant Hosmer and Sub-Assistant Ogden with a party in the schooner G. M. Bache, after the completion of a local survey on the south side of the Savannah River, of which mention has been already made.

Near the middle of February Mr. Ogden started work with a plane-table on the western side of the "Florida Passage," and by the end of March mapped the ground which borders that side of the passage between the Ogeechee River and Medway River, taking in the vicinity of Sunbury, at the head of St. Catharine's Sound. In this quarter his survey comprised twenty-six square miles. Assistant Hosmer meanwhile prosecuted the survey between the Medway and the upper part of Sapelo Sound, including the intervening parts of North Newport and South Newport Rivers, the courses of which are shown on the Progress Sketch No. 8. The ground represented by the upper sheet is nearly all firm land, but marsh mostly prevails between the Medway and Sapelo Sound. On the 1st of April the party was discharged, the vessel being unserviceable for continuing the work. A synopsis of statistics is thus presented in the concluding report of Assistant Hosmer:

Shore line traced	101 miles.
Creeks and marsh	195 "
Roads	85 "
Area of topography, (square miles)	72 "

Assistant Hosmer passed the working season at the north in active duty in Sections I and II. Sub-Assistant Ogden was employed during that period in the same sections. The first is now ready to resume duty in Section V, and Mr. Ogden has been assigned to service in the naval expedition for exploring the Isthmus of Darien.

Topography of Altamaha Sound, Georgia.—This survey, made by Assistant W. H. Dennis, with a party in the schooner Caswell, completes the plane-table work of the coast of Georgia north of St. Simon's Sound. South of it no entrance remains unsurveyed, and early provision will be made for tracing and sounding the water passages that lead behind Cumberland Island in courses southward to Fernandina Harbor.

Mr. Dennis took the field on the 15th of December, and closed work on the 15th of May. His survey (Sketch No. 8.) takes in the whole of Altamaha Sound, and all the contiguous waters between Darien River on the north and St. Simon's Sound. Of these intervening passages the principal ones are Buttermilk Sound, Hampton River, South Altamaha River, Mackay's River, and Back River, on which the topography of this year joins in the immediate vicinity of Brunswick, with plane-table work done previous to the year 1861, by Assistant Longfellow. In reference to the character of the triangulation which was the basis for his survey Mr. Dennis says: "The triangulation is admirably adapted to the requirements of the topographer, and although

it is ten years since the stations were occupied no difficulty was experienced in re-establishing the points for plane-table work."

Mr. O. H. Tittmann served as aid during the season, and accompanied Mr. Dennis for duty, which has been stated under Section I. The survey of the winter includes the city of Darien, and the topographical sheets distinguish the lands at present cultivated for the growth of rice and cotton. With the exception of creeks and rivers about Wolf Island and the eastern part of Hampton River, adjacent to the entrance of Altamaha Sound, Mr. Dennis found the waters fresh during the winter season, and the banks of the streams covered with a growth of reed or wild cane, often ten or twelve feet high. On all sides the work here noticed joins with surveys of former seasons. The statistics are as follows:

Shore-line surveyed	238	miles.
Creeks and marsh line	160	"
Rice dikes	85	"
Roads	55	"
Area in square miles	134	"

The arrangements of Mr. Dennis are now made for taking up the plane-table survey of Cumberland Island.

Topography of St. Simon's Island, Georgia.—This detailed survey was made in March, April, and May by the party of Assistant C. T. Iardella, with the schooner Bailey. After conferring with Assistant Dennis, who was at work to the northward of St. Simon's, Mr. Iardella began on the north side of Hampton River, (Sketch No. 8,) and made a plane-table survey of the lower part of Little St. Simon's Island. There a junction was made of the work of the separate parties. Long Island was then surveyed in detail, and the outside shore-line was extended southward to the lower end of St. Simon's Island, including also the shores of the inland passages and marshes. Of Village Creek, which bounds Long Island on the west, Mr. Iardella reports: "It is wide, with a depth of six to eight fathoms of water, and is navigable for large vessels from the entrance at Hampton River up to Wyley's Village." Of St. Simon's Island, which also was surveyed in detail, he says: "East and west it is bounded with marsh, which is overflowed at high spring tides. St. Simon's abounds in various kinds of wood, pine and live oak predominating."

The south branch of the Altamaha River is included within the plane-table limits of this season's work. In that vicinity Mr. Iardella joined with the topography done previous to the war by Assistant Longfellow, and completed the survey of St. Simon's Island by tracing the shores of Frederica River.

Mr. Eugene Elliott served as aid in the topographical party. The statistics of work done are as follows:

Shore-line surveyed	32	miles.
Roads	22	"
Creeks	58	"
Area, (square miles)	35	"

Assistant Iardella is now making preparation to resume field duty in Section VII.

Hydrography of St. Andrew's Sound, Georgia.—This work was commenced by Assistant Halter on the 2d of March, and was closed on the 20th of May. The hydrographic sheet shows the character of the bottom in the approaches to St. Andrew's and Jekyl sounds, and also the soundings north of the entrance, the work being carried up to a connection with the survey of the bar at St. Simon's Sound, as shown on Sketch No. 8. Inside, the soundings were extended as far as the southwestern end of Jekyl Island. The party in the steamer Endeavor and the aids, Messrs. Bissell and Vinal, were employed in two other sites of work in this section. In the survey of St. Andrew's Bar and approaches Assistant Halter erected thirty signals and occupied thirty-three stations. Other items of the statistics are as follows:

Miles run in sounding	716
Angles measured	4,462
Number of soundings	53,656

Reference to the subsequent occupation of Assistant Halter has been made under the head of Section III.

Fernandina Bar range-lights.—Before engaging in the work at Charleston Bar, noticed under a preceeding head, Assistant Halter, with his party in the steamer Endeavor, ran lines of soundings across the bar of St. Mary's River, in the vicinity of Fernandina, Florida, for the purpose of re-establishing beacon range-lights. This duty was performed between the 8th and 24th of January. Two positions for lights were selected at the north end of Amelia Island, and were carefully marked for the uses of the Light-house Board. The report of Assistant Halter has been transmitted to the chairman of the board, with a chart of the work, showing also the positions selected for the proposed beacons. A synopsis of the hydrographic statistics is thus given in the report:

Miles run in sounding	42
Stations occupied with theodolite	10
Angles measured	580
Number of soundings	3,944

SECTION VI.

ATLANTIC AND GULF COAST OF THE FLORIDA PENINSULA, INCLUDING THE REEFS AND KEYS, AND THE SEA-PORTS AND RIVER.

Hydrography of the Florida Reef.—The hydrographic party of Acting Master Robert Platt resumed service in the vicinity of the reef on the 7th of January, with the steamer Bibb. The work laid out for the season was the completion of lines of soundings extending from the reef to the trough of the Gulf stream, and the further development of the submarine rocky terrace or plateau, examined in former years, in the region between Sand Key and Tennessee reef.

Lines radiating from the group of the Tortugas, and others off the Rebecca Channel, the quicksands, and off the Marquesas, were sounded out; and later in the season similar lines to the eastward of Tennessee reef, and nearly to Cape Florida, were run at distances of about ten miles apart. Assistant L. F. Pourtales, who accompanied the party during the whole season, made dredgings at every sounding station, and in the aggregate procured a large collection of deep-sea forms of life, a great many of which are new to science. A considerable number of his specimens have been identified with species inhabiting the deep-sea bottom on the coasts of northern Europe where they have probably been transplanted by the Gulf stream.

In prosecuting the general hydrography it was noticed that the currents along the Florida reef were remarkably changeable. Referring to them Acting Master Platt says: "Some days the current was running at the rate of 2.8 miles per hour, but on other days only 0.6 of a mile the hour. The set of the current was to the northward and eastward, except at one position, thirteen miles off Sand Key light-house, the current at that position running S.SW. three-tenths of a mile per hour."

In sounding on a line between Carysfort light and Orange Key, one of the Bahamas, the current running eastward was observed to have a width of about thirty miles. "After passing through this current we came suddenly into water free of current, and in the remaining distance (about thirty miles) to the Bahamas the ship made her course good." The steamer left Orange Key on the 2d of April to return to Carysfort light, the wind then blowing very fresh from the south. As before, no current was experienced in steaming twenty miles westward, and then the eastward current was met, having a rate of three miles per hour.

On the 24th of February Professor Agassiz was received on board of the steamer Bibb at Havana. The vessel was for two months following employed in sounding and dredging, first along the coast of Cuba and across St. Nicholas Channel to the Double-headed Shot Keys, and across the Gulf stream towards the reef; afterwards in the neighborhood of Carysfort light, and in the vicinity of the reefs to the eastward of it. The weather was very unfavorable during this part of the season, but, though little could be accomplished in the way of deep-sea dredging, large collections were made of specimens and of facts bearing on the formation of the reef and keys corroborating and completing the observations previously made by that eminent naturalist. When

the professor's observations were closed, he was taken in the steamer Bibb as far as Cedar Keys, visiting on the way Charlotte Harbor and Egmont Key.

The steamer returned to Norfolk, Virginia, on the 9th of June, and after refitting was employed in hydrographic duty, which has been mentioned under the head of Section IV.

Sub-Assistant Gershom Bradford was attached to the hydrographic party, and Mr. J. B. Adamson served as aid.

Among the incidents attending the cruise of the Bibb was the rescue of the captain and crew of the schooner *Americus* which had gone on the Lavender Rocks, about three miles east of Key Sal. The vessel was got off, but foundered at an anchorage under the lee of Key Sal, to which she had been towed by the steamer.

Relief was rendered also to the British ship *Golconda* in towing that vessel off a dangerous shoal in the harbor of Key West, where she had grounded on the top of a spring tide.

Efforts made, at the request of the American underwriters' agent at Key West, in behalf of the capsized brig *Omaha* were unsuccessful, the vessel grounding fast while in tow of the steamer.

In the course of the season the currents were observed by the hydrographic party at fifteen stations, and depths were determined by about seven hundred soundings. The site of the operations is shown on Sketch No. 9.

An interesting paper, comprising the observations made on the reef by Professor Agassiz, is given in the Appendix No. 10. The results of operations conducted by Mr. Pourtales are also given in the Appendix, (No. 11,) together with a short review of the history of such researches on the Atlantic coast of the United States.

SECTION VII.

GULF COAST AND SOUNDS OF WESTERN FLORIDA, INCLUDING THE PORTS AND RIVERS. (SKETCH No. 10.)

Triangulation and Topography of St. Andrew's Bay, Florida.—The work in this section, consisting of triangulation and topography, has been regularly continued from the points where the parties left off at the close of the last season. Of the two parties engaged, one was employed at St. Andrew's Bay, and the other to the westward of Pensacola entrance. The party of Assistant S. C. McCorkle reached its site of work with the schooner Torrey early in December, 1868. At the entrance to St. Joseph's Bay (north) the triangulation was resumed, and was extended to the northward and westward along the coast of Florida, in a series of quadrilaterals that embrace the waters of St. Andrew's Bay. In 1855, a partial survey of the bay was made, for the immediate benefit of commerce, in advance of the regular work then in progress. Many of the stations of the old survey have been destroyed, and others have washed away during violent gales. It may, therefore, be impracticable to compare outlines given by the old and by the recent triangulation, except so far as the topographical sheets may avail for the purpose. Mr. McCorkle reports that the inlets at the eastern end of St. Andrew's Sound and western end of Hurricane Island (Sketch No. 10) have closed, and that many changes have taken place in the shore-line of St. Andrew's Bay.

Sub-Assistant H. M. De Wees was attached to the party of Assistant McCorkle, and under his direction made a plane-table survey of the coast of Florida between St. Joseph's Bay and St. Andrew's Point, joining on with the topographical survey of 1855. The shore-line is a level, hard beach, varying in width between fifteen and forty meters, and backed by a sand ridge from six to twenty feet high. The country is wooded, the growth being chiefly pine, with here and there an oak, cypress, or palmetto tree. Mr. De Wees also refers to the changes, especially of shore-line, which have occurred since the first survey. A narrow strip of sand has been formed, connecting St. Andrew's Point and Crooked Island, making the latter a portion of the main land. The peninsula formerly known as "Little East Pass" has been completely obliterated.

On the 1st of June the party was discharged. The records and computations were soon after forwarded to the office, and the plane-table sheets were inked and turned in without delay. The following statistics show the progress of the party:

Signals erected	15
Stations occupied	15
Angles determined	95
Number of measurements	3,732
Shore-line traced, (miles)	27
Roads, (miles)	4
Area of topography, (square miles)	9

During the summer and autumn of the present year, Assistant McCorkle and Sub-Assistant De Wees were employed in Section I.

Gulf Coast Measurement.—The geodetic connection of the triangulations on Mobile Bay and on Pensacola Bay has been completed by the direct linear measurement of a distance of ten miles. This operation included the measurement of angles requisite for carrying forward the directions, and also the observations for azimuth at West Gulf shore station, the point of junction with the lines brought westward from Pensacola. Assistant J. G. Oltmanns was occupied in this service from the 26th of December until the 1st of March of the present year.

With a view to greater dispatch, the linear measurement was made according to a plan suggested by Assistant J. E. Hilgard, with a steel tape or ribbon, twelve meters in length, one of those manufactured under the patent of Mr. H. W. Paine. It is a ribbon of steel, about one-sixth of an inch wide, and of the thickness and temper of a watch-spring. The tape was well adapted to the purpose to which it was applied on the Gulf coast, being easily handled, not liable to twist or to take permanent bends, and it could readily be extended to its entire length. Assistant Oltmanns thus describes the mode of measurement:

"In order to ascertain with great precision the effective length of the steel tape, as used in the actual measurement, I first measured with the contact-slide apparatus a distance of 264 meters, and afterward the same distance twice with the steel tape. I also carefully laid off twelve meters with the same apparatus, and compared the steel tape with that length, due note being taken of temperature. The length of the steel tape at 32° Fahrenheit was thus found:

"By first measurement	12.0073
"By second measurement	12.0074
"By third measurement	12.0078
"Mean	12.0075

"In making the measurements of the lines along the coast, four tripod stands were used, each having a piece of soft wood fastened on its top. One of the tripods was set up over the point of commencement, in the vertical of which a pin was inserted on top of the stand. Each succeeding stand was set up as nearly as practicable at a distance of twelve meters from the preceding one. Two men carried the tape, the rear one being careful to hold the mark denoting the zero point on the tape, exactly on the pin head, without at all disturbing the trestle. At this end the tape extended about ten inches beyond the zero point, in order to give ample space for the hand of the operator back of the tripod head. The forward man then drew the tape taut, and when the rear man called 'all right,' I marked the twelve-meter spot by slightly driving a very fine steel pin into the exact place, to mark the beginning of the second length, and so on. While the two men held the tape in position, I attended to the alignment, and to the inclination which is read off by a simple level sector attached to the stand, while two other men set the next trestle or tripod stand, one laying off the proper distance with a string, keeping the general line over the ground, and the other fixing the trestle. A very exact and rapid measurement was thus made."

The apparatus used by Assistant Oltmanns is represented in Sketch No. —, accompanying this report. Sixteen thousand eight hundred meters, or about ten and a half miles, were measured in this way, at an average rate of one length of tape per minute, or one mile in eight hours.

For the rectification of the line, and its varying directions, twenty-seven angles were measured at nineteen points in the line of measurement, by 850 single observations. Fifteen sets of azimuth measures were made at the point of junction "West Gulf Shore" with Transit No. 10, by observations of Polaris, referred to a mark by means of the azimuth screw, in the mode described by

Assistant Hilgard in Appendix No. 27 of the annual report for 1856. The several results show a good accordance, and the observed azimuth of the terminal line agrees with that brought forward from Fort Morgan, within a second of arc, checking the work in a satisfactory manner.

Mr. Oltmanns acknowledges the assistance, kindly rendered, by Captain Spencer, of the revenue steamer Delaware, in transporting his party from Mobile to the field of operations, and in returning after the close of the season. In passing from West Gulf shore-station to Fort Morgan, Mr. Oltmanns lost, by the sinking of a boat, some valuable papers and clothing of his own, but rescued the instruments and records without damage. At Fort Pickens he measured some angles additional to those connected with previous work, and examined, with reference to their preservation, the stations on the beach between that point and Perdido Entrance.

Assistant Oltmanns is now engaged with a party in topographical and hydrographic service in the vicinity of Cape Sable, on the Florida peninsula.

Solar eclipse of August 7, at Shelbyville, Kentucky.—Arrangements were made in the latter part of June for observing the total eclipse of the sun at several stations in the State of Kentucky. Assistant George W. Dean was directed to organize an astronomical party that might co-operate with a party conducted by Professor Joseph Winlock, director of Harvard Observatory, by whom ample preparation had been made for observing the special phenomena of the eclipse.

Shelbyville, although a few miles north of the central line of the shadow to be projected by the moon, was in other respects a favorable position for the intended observations. Moreover, the large equatorial belonging to the college at Shelbyville, and several rooms in the building, were placed by the board of trustees at the service of Professor Winlock for the special use of the parties on the occasion.

By the middle of July, Assistant Dean had his equipment of instruments in place in a temporary observatory. Between the 24th of that month and the 3d of August, Sub-Assistant F. Blake, jr., made a series of latitude determinations with the zenith telescope, C. S. No. 6, recording 164 observations in observing upon fourteen pairs of stars. The micrometer divisions were ascertained from forty observations upon Polaris near eastern elongation.

All being in readiness, and the weather being highly favorable, on the 7th of August Mr. Dean and Mr. Blake succeeded in recording the times of the four contacts during the eclipse, and they also observed, very satisfactorily, the occultation of six of the solar spots. These instants were all recorded on the chronograph register. The instrument used by Mr. Dean was an achromatic refractor, formerly used as a "finder" on the large equatorial at Harvard Observatory. It has a focal length of 46 inches; aperture, 3 inches; the amplifying power used was 30; and it was equatorially mounted.

In referring to the remarkable phases of the eclipse, Mr. Dean mentions that he saw within fifteen minutes after the commencement of the total phase, ten faint objects pass across the moon in a southwesterly direction. These were first pointed out by Professor Winlock, and, in his opinion, were meteors. The same phenomena were observed by Mr. Blake, and by Messrs. Alvan G. Clark and George D. Clark, members of the party of Professor Winlock.

Mr. Blake observed with the comet-seeker belonging to Harvard Observatory, and noted the last three contacts of the moon and the occultations of five solar spots.

Professor C. B. Seymour, of Louisville, had the use of a small telescope belonging to the Coast Survey, and with it made such observations as he found practicable during the progress of the eclipse.

At the request of Professor Winlock, his party was attended by Mr. J. A. Whipple, an experienced photographer of Boston, with all the appliances needful for taking photographic pictures of the phenomena that might be successively presented. For this interesting and important branch of operations, Mr. George D. Clark, of Cambridge, gave his services as an assistant to Mr. Whipple. The photographic apparatus was used in connection with the small equatorial telescope of Harvard College Observatory, provided with an excellent clock movement. The aperture of the instrument is five and a half inches, and its focal length seven and a half feet. Eighty good "negative" pictures were made by Mr. Whipple during the progress of the eclipse, of which three were taken during the total phase, the instants in all cases being recorded on a chronograph register. Prints subsequently made from the negative representing the corona, plainly show its symmetrical

arrangement about the axis of rotation of the sun, and its relation to the axis was at once recognized by Professor Winlock, the corona being flattened at the poles and enlarged at the sun's equator, as was also indicated in the photographs made at Springfield, Illinois, under my immediate direction. Many other particulars of great interest will be found in the comprehensive report made by Professor Winlock to the authorities of Cambridge observatory. The details observed at my request were such as would connect with the observations of precision. His researches with the spectroscope, independent of those just referred to, will doubtless be of great value. In that branch of research and in the observation of physical phenomena generally, Mr. Charles S. Peirce, of the Coast Survey, co-operated at Bardstown, Kentucky, and was assisted by Professor N. S. Shaler, of the School of Mining, Harvard College. Professor J. Lawrence Smith also observed with the spectroscope at Bardstown.

The station at Shelbyville was in the southwestern part of the grounds belonging to Shelbyville College. Several rooms in the college were placed at the disposal of the observing parties by the board of trustees. Assistant Dean expresses his acknowledgments for the aid also rendered by the Rev. Dr. Waller, Dr. Baker, Colonel William Winlock, Colonel M. C. Taylor, Joseph W. Davis, esq., and R. C. Tevis, esq. The gentleman last named volunteered his services for recording the temperature, readings of the barometer, &c., and made records at intervals of fifteen minutes during the eclipse.

Sub-Assistant F. H. Agnew, of the Coast Survey, had charge of the chronograph registers and obtained excellent records of the instants at which observations were made with the instruments of the observing party. Unfortunately his eyesight had been so much impaired by severe duty in the longitude party at Salt Lake City during the previous winter, as to make it impracticable to observe with a separate instrument.

Falmouth and Oakland, in the State of Kentucky, were regarded as favorable points for observing the eclipse just within the limits of the shadow. The requisite arrangements were made at Falmouth by Mr. Arthur Searle, of Harvard Observatory, and he was fortunate in securing the co-operation of several gentlemen of intelligence at that place. The chief object was to determine the duration, more or less, of the total phase. Mr. Searle's observations, by an accident, were not well recorded on the Morse-Fillet register, but he reports that Captain W. E. Arnold, who was assisted by Messrs. Johnson, Yelton, and Woodson, determined the duration of totality to be forty-five seconds at Falmouth. Judge Hudwall and Mr. R. W. Grant observed from the hill just north of Falmouth Station, and from their observations the time of the total phase was forty-one and a half seconds.

At Catawba, a few miles north of Falmouth, Mr. D. Crozier, jr., determined the duration of totality to be twelve seconds. All these subsidiary stations were marked by Mr. Searle, for determining, when connected with stations near the south limit, the breadth of the shadow projected by the moon.

At Oakland the observations were conducted by Professor S. P. Langley, director of the observatory at Allegheny, in Pennsylvania. He was assisted by Graham Wilder, esq., and Mr. N DeBree, of Louisville. The observations gave for the duration of totality only two seconds.

The stations at Falmouth and Oakland were connected by telegraph, and clock signals were sent from Oakland to all the telegraph stations in the vicinity, and thus many of the operators were enabled to determine the duration of totality with a fair degree of precision.

Assistant Dean in his official report acknowledges his obligations to John Van Horn, esq., general superintendent of the Western Union Telegraph Company, and also to Messrs. Carter and Boyle, telegraph managers at Louisville, for facilities of great value to the success of the operations in Kentucky. The preceding occupation of Mr. Dean will be referred to under the head of Section X. His report on the observations made by the party under his direction at Shelbyville is given at length in the Appendix, No. 8.

SECTION VIII.

GULF COAST AND BAYS OF ALABAMA, AND THE SOUNDS OF MISSISSIPPI AND OF LOUISIANA TO VERMILION BAY, INCLUDING THE PORTS AND RIVERS. (SKETCH No. 11.)

Solar eclipse of August 7, *at Springfield, Illinois.*—The party organized to observe under my immediate direction the phenomena of the total solar eclipse was placed in the general charge of Assistant Charles A. Schott, chief of the computing division of the Coast Survey Office. Assistant L. F. Pourtales, an experienced observer, was also of the party, and with him were associated Professor James M. Peirce, of Harvard College, and Messrs. E. P. Seaver, R. A. McLeod, J. B. Warner, C. N. Fay, and W. P. Montague, of the same institution. A most important adjunct in photographic apparatus was provided by Mr. J. W. Black, of Boston, who also accompanied the party with his assistant, Mr. Richard Fitzgerald. This branch of service was strengthened by the addition of Messrs. Sexton and German, photographers, of Springfield, whose aid proved to be of great value.

The duty assigned to the party was to obtain measures of precision of the contacts, and to make such collateral observations of the phenomena of the eclipse as the instrumental outfit would allow. As will be mentioned elsewhere, the astronomical latitude and longitude of a station in Springfield had been previously determined by the party of Assistant Goodfellow. That determination was transferred by Assistant Schott geodetically to a station suitable for the intended observations, in the grounds adjoining the water-works, about a mile and a quarter northeast of the city. In effecting the transfer, a base line was measured, and also the azimuth, and the requisite angles of a small triangulation. Incidental to this, the positions of several prominent objects in the vicinity of Springfield were geodetically determined.

The local time was obtained from transits with the Troughton & Simms transit instrument C. S. No. 4; the Krille astronomical clock; and the chronograph (Bond) C. S. No. 2. The local battery used consisted of three Daniell cups, and was kindly lent for the service of the party, from the Western Union telegraph office at Springfield.

The clock corrections were deduced with special care by Messrs. Schott and Pourtales from observations made on the 3d, 4th, and 7th of August, previous to the eclipse. On the 5th and 6th it was cloudy and at times raining, but on the 7th the sky was clear; no cloud was seen; and the atmosphere was free of dust. Time signals were sent on the 6th and 7th to Assistant J. E. Hilgard for the use of his party stationed to observe the eclipse at Des Moines in Iowa.

At Springfield, transits of solar spots were observed and noted on several days before and after the eclipse, according to Carrington's method, but neither of the telescopes available for the party being provided with clock movement, such observations were secured at a disadvantage.

Photographic pictures during the eclipse were made in the principal focus of the object glass of the equatorial telescope C. S. No. 1, and corresponding to the focal length of the instrument they are about two-thirds of an inch in diameter. The equatorial was so adjusted that by merely turning the handle for effecting motion in right ascension, the images could be kept quite near to the middle of the field during the eclipse. In photographing, the light at the object glass was restricted to an aperture of only about two inches in diameter. The pictures were taken instantaneously. As the drop slide passed transversely through the axis of the telescope, the galvanic circuit was broken automatically for about one-tenth of a second, and thus for each picture the time was recorded on the chronograph. At intervals of about nine seconds during the eclipse Mr. Black took one hundred and seventy-eight sharply defined pictures of the sun and moon in conjunction. Though small in diameter, the negatives are of such general excellence and were so precisely timed, that they may be expected to give, by careful measures under the microscope, results for the times of contact that will considerably exceed in value such observations when made by the eye. The pictures were timed by Assistant Pourtales. Mr. Black attended at the instrument in person, as photographic operator.

Independent observations were made by Assistant Schott with the zenith telescope C. S. No. 5, and a magnifying power of about 65, a red shade glass being fastened to the inverting eye piece. Mr. Seaver used the small equatorial from which the sun's image was thrown on a white screen

showing a disk 4¾ inches in diameter. Mr. McLeod observed with a binocular marine glass, and Mr. Fay with a telescope of two inches aperture. Red-shade glasses were used by all the observers. The beats of the chronometer were called aloud by Mr. Montague.

All the observers noted the times of the contacts, and the resulting values are compared in the report of Assistant Schott (Appendix No. 8) with the predicted times given by data in the American Ephemeris and Supplement. Among other interesting particulars in that comprehensive report, it is noticed that the phenomena known as Baily's beads were seen by several of the party; and Mr. Schott, in observing the occultation of the largest spot on the sun, noticed the formation of a black band of junction between the moon's advancing limb and the umbra of the spot. The Appendix referred to is a careful synopsis of the observations made by the several members of the party at Springfield and of the results deduced from them.

Preceding the time of the eclipse, Professor J. M. Peirce and Mr. Warner were detached from the party and sent to Bloomington, Illinois, to observe the phenomena at a station on the computed line of two minutes duration of totality. This duty was successfully performed and valuable results were obtained.

Latitudes and longitudes in Illinois, Iowa, and Nebraska.—The geographical positions of points selected as stations for observing the solar eclipse of August were determined by Assistant Edward Goodfellow, aided by Mr. E. P. Austin.

The use of the Western Union telegraph lines having been liberally granted by General Anson Stager and General J. J. S. Wilson, of Chicago, and arrangements made with the superintendents of the western railroads, who readily gave free transportation for observers and instruments, Mr. Austin was sent successively to Mattoon and Springfield in Illinois, and to Burlington and Des Moines in Iowa. Assistant Goodfellow remained at Omaha, the longitude of which he had determined by the telegraphic method in connection with observers at Cambridge and San Francisco. Mention will be made of this service in the next section.

On the 27th of April, and on the nights of the 2d and 3d of May, signals were successfully exchanged between Mattoon and Omaha. Mr. Austin, after completing observations for the latitude of Mattoon, proceeded to Springfield. There the work was much delayed by unusually wet and stormy weather, so that observations for latitude were not finished until the 6th of June. Signals for longitude, however, were obtained on the 22d of May and on the 2d and 4th of June. Burlington was occupied during seven days in June, signals being exchanged between the observers on the 17th, 21st, and 22d of that month. Similar observations were made at Des Moines on the nights of the 8th, 9th, and 10th of July.

At each of the stations the position of the center of the transit was permanently marked by a block of stone with a copper bolt, and meridian lines were established by placing a second block, similarly marked, due north or south of the main station. Descriptions of these markings for identifying the stations readily are inserted in the record-books.

Duplicates of the records of observations for latitude and difference of longitude have been received from Assistant Goodfellow and deposited in the Office.

At the request of General Robert R. Livingston, surveyor general of the district of Iowa and Nebraska, Mr. Goodfellow exchanged signals for difference of longitude with O. N. Chaffee, esq., who was engaged in running the western boundaries of the State of Nebraska. Two stations in the State, namely, Bushnell and Julesburg, were thus determined in longitude.

The field-report mentions the acknowledgments due to General C. C. Augur, commanding the Department of the Platte, who lent military tents for the use of Mr. Austin's party. Messrs. W. B. Hibbard, district superintendent of the Western Union Telegraph lines, and Frank Lehman, office manager at Omaha, also gave prompt and courteous aid in furthering the telegraphic work.

The correct geographical positions of the points occupied by Assistant Goodfellow and Mr. Austin are stated in the Appendix, No. 8.

At the request of Major Blickensderfer, the Government commissioner, signals for determining the longitude of North Platte, a station in Nebraska, and of Rawlings, in Wyoming Territory, on the line of the Union Pacific Railroad, were exchanged between that officer and Mr. Austin, while the latter was at Omaha. The notes of these observations were taken to the Coast Survey Office

by the commissioner, who soon left for Washington, and the results were computed in accordance with his request.

Solar eclipse of August 7 at Des Moines in Iowa.—The party under the direction of Assistant J. E. Hilgard was equipped with the means of making the observations of the contacts of the sun and moon, and noting the attendant phenomena. Assistant Edward Goodfellow, Mr. J. H. Lane, of Washington City, and Dr. T. C. Hilgard, of St. Louis, accompanied as observers. Lord Sackville A. Cecil, of England, having applied for permission to join, was associated with the party.

As at the other station on the path of the eclipse east of the Rocky Mountains, the sky was perfectly clear, and a very satisfactory view of the phenomena was obtained. The instants of the several contacts were noted by Assistants Hilgard and Goodfellow; those of only the external contacts by Mr. Lane, whose attention at the time of totality was directed to other phenomena. During that phase Dr. Hilgard made drawings of most of the protuberances which showed on the edge of the sun, and especially delineated in full detail the remarkable one on the lower edge. A full report of the results will be found in the Appendix, No. 8.

The observing station at Des Moines was in the court-house square. Its geographical position, as mentioned in the preceding notice of work in this section, had been determined under the direction of Assistant Goodfellow. A transit-instrument was mounted for observations of local time, which were obtained on the afternoon of the eclipse. The chronometers used were compared by telegraph with the clock used by the observing party at Springfield in Illinois.

Assistant Hilgard, availing himself of the opportunity, made observations for determining the magnetic elements at Des Moines, and thus procured additional data for the chart of magnetic lines, the last edition of which was published in the Annual Report of 1865. These determinations by an observer of great experience are of special value, the station being far removed from those upon which the traced lines on the chart have hitherto depended.

Assistant Hilgard organized, in addition, two parties for the determination of the limit of totality north and south of the line along which the total eclipse was also central. One of the parties was directed to the southern limit near St. Louis in Missouri, the other to Cedar Falls in Iowa. At both stations satisfactory observations were obtained, from which the limits may be inferred with great precision. Near St. Louis the arrangements were kindly undertaken by Major J. Pitzmann, county engineer, who, aided by Messrs. Eimbeck, McMath, Soldan, Cobb, McKown, Burgas, and Schmidt, occupied five positions arranged across the path of the shadow at distances one mile apart, and observed the duration of totality, which, at the station nearest to the limit, was only ten seconds. The geographical positions of these points have since been determined by Mr. O. H. Tittman and Professor William Eimbeck, who observed for latitude and longitude at the Washington University in St. Louis, and connected the eclipse stations by a survey.

The observations at Cedar Falls were arranged by Dr. A. Horr, of Dubuque, and were made by Messrs. E. W. Horr and W. J. Anderson, of Dubuque, and J. H. Stanley, of Cedar Falls, at three different points, the geographical positions of which were afterward determined by Sub-Assistant F. Blake.

The practical sagacity of Assistant Hilgard led him to improve the opportunity afforded by his operations for giving data by which to increase the value of local maps of the region adjacent to his stations. Both at St. Louis and Cedar Falls the astronomical stations were connected with the public-land surveys by ascertaining their position relative to the nearest section corner. The stations will thus serve to assign correct places on the map to certain portions of those surveys, which, however adequate to their immediate purpose of parceling out the land for sale, afford only imperfect means of making a map of the country.

Through the assistance of Dr. Horr the locations of two other points on the northern border of the eclipse were also ascertained, at which the total obscuration lasted but a moment, while at a short distance the light was obscured but did not entirely disappear. Due weight will be given to these observations as to the others in the general discussion of results.

Triangulation and topography of Isle au Breton Sound, Louisiana.—The party of Assistant C. H. Boyd was organized for this service early in January, and before the close of that month commenced work with the schooner James Hall. The signals used in the triangulation were tripods of sixteen and twenty feet in height, with cast-iron heads of a form devised by Assistant Boyd. When

observing, the theodolite rests upon the head of the tripod, the iron at other times supporting merely the signal-pole. By this expedient horizontal angles were measured above the level of the mangroves and reeds that fringe the shores of the sound. The greatest elevation attainable was required to bring into view at Point au Sable the signals set on Isle au Breton. Sketch No. 11 shows the work done in two chains of triangles extending from the limits reached by the same party in the preceding season. One of these chains passes in a northeasterly direction across Isle au Breton and Grand Gosier, toward the Chandeleurs; the other covers the main western shore and adjacent islands, and stretches in a northerly direction as far as Point Chico.

Within an aggregate length of seventy miles in triangulation, Mr. Boyd and Sub-Assistant H. L. Marindin, who was attached to the party, surveyed 212 miles of shore-line with the plane-table. The topography is on five sheets, and was accomplished under much hardship, arising as well from unfavorable weather as from natural obstacles to progress on this part of the Gulf coast.

As incidental to the work of the season, Assistant Boyd selected and marked a suitable site for a light-house on Grand Gosier, at a point about midway between the Chandeleurs and Pass à Loutre. The land on that island is the highest and the most stable found by the party in the range of work for the season.

The statistics of triangulation are as follows:

Stations occupied	38
Signals erected	35
Angles measured	137
Number of observations	1,836

During the summer, and until the end of October, Mr. Boyd was engaged in a survey that has been described under Section I. Mr. Marindin was at the same time in special hydrographic service under the direction of Assistant Mitchell, and is now under orders to accompany the Darien exploring expedition.

The survey is about to be resumed in Isle au Breton Sound.

Hydrography of Isle au Breton Sound, Louisiana.—The party of Assistant F. P. Webber, with the schooner Varina and steam-launch Barataria, reached this site of work on the 20th of January, and at once set up a tide-gauge, as usual, before commencing the hydrography. The tides being irregular, observations were taken every half hour, day and night, in order to get a good determination of mean low water. The mean rise and fall of tide was found to be 1.1 feet.

At all favorable intervals the soundings were prosecuted from Pass à Loutre in a northwest and north direction to Isle au Breton and Grand Gosier, (see Sketch No. 11,) and the lines were crossed by others stretching from the west side of the sound to the same islands. Soundings were extended also from these islands toward the main shore to the northward, the distance in that direction varying from six to ten miles. The hydrographic sheet shows that a shoal extends from the end of Grand Gosier, in a southwest direction, to a distance of about twelve miles; in fact, overlapping the eastern end of Isle au Breton, and leaving only a very narrow channel between the two islands. The shoal is dangerous, having in some places as little as three feet of water. It breaks in all heavy blows from the Gulf.

Owing to the low level of the shores, Assistant Webber was under the necessity of erecting several scaffolds thirty feet high, as signals for the use of the boat-party in sounding. The currents in the sound were found to be very strong, and all north and east winds made the water very rough. Outside from Pass à Loutre the current in all ordinary weather set strongly toward the northeast, but nearer shore the current was found to set up and down between the islands, with the flood and ebb tide. In reference to the channels and character of the sound, Mr. Webber remarks: "To the northwest of Isle au Breton the water is shoal, and there are a great many lumps with twelve feet water on them, or less, and there is no passage across except for light-draught vessels." "From Point au Sable there is a channel with about fifteen feet of water, making up toward the west for a distance of six miles, and heading near the mouth of Fort Bayou. To the north and east of it there is a large shoal."

The hydrographic work was continued until the middle of May, when the vessel was laid up for the season at the head of the passes in the Mississippi.

Sub-Assistant F. D. Granger, and Mr. R. B. Palfrey, aid, were attached to the party in the Varina. Mr. W. T. Angell served as temporary aid.

In the field-report acknowledgment is made of the assistance kindly rendered to the party during this and in the preceding season by Captain E. A. Freeman, of the revenue-cutter Wilderness. By the hearty co-operation of that officer, where his aid could be given without interfering with his own special duties, the work was much favored. The following is a summary of the statistics:

Miles run in sounding	1,166
Angles measured	2,394
Number of soundings	52,539

Under Section I mention has been made of the subsequent occupation of this party. The hydrographic work in Isle au Breton Sound is about to be resumed.

SECTION IX.

GULF COAST OF WESTERN LOUISIANA AND OF TEXAS, INCLUDING BAYS AND RIVERS. (SKETCH No. 12.)

Longitude and latitude of Omaha, Nebraska.—The advanced progress of the survey of the coasts of the United States has for several years made it desirable that the work on the Pacific coast should be connected with the surveys on the Atlantic coast and on the Gulf of Mexico, by telegraphic longitude determinations across the continent. Favorable circumstances which presented at the opening of the present season made the decision easy in regard to undertaking the work without further delay. The detailed arrangements were intrusted to Assistant George W. Dean, and suitable preparation in the outfit of instruments and appliances was made by him in December, 1868, for occupying a station at Omaha, in Nebraska, and another at Salt Lake City, in Utah Territory, as points intermediate in the transcontinental series of longitude stations between Cambridge, Massachusetts, and San Francisco in California.

After completing the organization of the party which was to act under his direction, Assistant Dean proceeded to Salt Lake City early in January of the present year, leaving Assistant Edward Goodfellow at Omaha. The operations at Salt Lake City will be detailed under the head of Section X.

At Omaha an astronomical station was established by Mr. Goodfellow in the grounds of the old State-house. The ample facilities afforded by the officers of the Western Union Telegraph Company and by managers of the railroad companies of the West have been mentioned in referring to the operations of this party in Section VIII.

The observatory having been connected with the main wires, a preliminary trial of the line was had on the 7th of February, between Cambridge, Omaha, Salt Lake City, and San Francisco, and, the results being satisfactory, the work was carried forward until exchanges of clock-signals for difference of longitude had been obtained on six nights between Cambridge and Omaha. Operations at the first-named city have been described under the head of Section I. Successful exchanges were made on eleven nights between Assistant Goodfellow, at Omaha, and Assistant Dean, at Salt Lake City. On six nights signals were passed between the observers at Omaha and San Francisco.

Transit No. 6, spring-governor No. 2 and the Krille clock were used at Omaha in the longitude work. For the correction due to inequality of pivots of the transit-instrument, two sets of observations were made at altitudes ranging from 5° to 55°. The stars observed for time and thread intervals were taken from the American Nautical Almanac, and from a list prepared for the use of the longitude party by Professor Joseph Winlock, director of the Cambridge Observatory.

Upon the completion of the work the point which had been occupied by the transit was permanently marked by three blocks of limestone. The upper one, a cube of fourteen inches on a side, is level with the surface of the ground, and has inserted in it a copper bolt, to indicate the station point. North of this, at a distance of two hundred and eighty-one feet, three similar blocks were placed in position, the upper one with a copper bolt in the center, thus establishing a meridian line across the capitol grounds. The expense of procuring and setting the blocks was borne by the city.

Mr. E. P. Austin, of the Nautical Almanac Office, was temporarily attached to the party of Assistant Goodfellow, and ably co-operated in the service. The intensely cold and stormy weather, and the frozen state of the soil in January, made the work of putting up an observatory, and the subsequent processes, matters of much hardship and exposure.

For latitude, 173 observations were made on 35 pairs of stars selected from the British Association Catalogue. The value of the micrometer-screw was determined by two sets of observations on Polaris at western elongation, and the value of one division of the level in terms of the micrometer by two sets of observations upon a distant mark.

Under the direction of Assistant Goodfellow, a series of meteorological observations were recorded at Omaha by Mr. J. W. Barrett, who accompanied the astronomical party as a hand.

Magnetic observations at Omaha.—In one of the rooms of the old capitol building, Assistant Goodfellow made observations for the magnetic intensity, recording two series. The declination and dip of the magnetic needle were determined at a station below the hill, selected on account of its freedom from the local attraction due to the cast-iron pillars and window-sills in the old capitol. Three sets of observations were made with declinometer No. 1; and three sets with the dip-circle No. 8. The astronomical meridian was determined at the magnetic station in the usual way by observations on the sun.

After closing service in this section, Assistant Goodfellow was on duty at two stations in Section VIII, and is now in Section I, making preparation to receive and send time-signals for determining the difference of longitude between Duxbury, Massachusetts, and the eastern end of the French transatlantic cable, which is at Brest, on the coast of France.

Hydrography of Corpus Christi and Aransas Bays, Texas.—In preparing for this work, Sub-Assistant Horace Anderson fitted out the schooner Stevens at Galveston, and reached Corpus Christi with his party on the 15th of January. Two tide-gauges were established, one at Ingleside Harbor, and the other at the "Dug Out," leading into Aransas Bay. The soundings made previous to the end of May define the character of the lower part of Aransas Bay, the shore approaches of Corpus Christi Bay, and the channel leading from the bay out into the Gulf of Mexico through Corpus Christi Pass. In these several bodies of water, the maximum depth found was fourteen feet, gradually shoaling toward the shore.

"Directly in front of the town of Corpus Christi, and about half a mile distant, are two reefs on which the depth of water is only four feet. They overlap each other, and the channel between them is intricate."

"Between Corpus Christi Bay and Laguna Madre the pass is narrow, and has only two and a half feet of water. In the 'Dug Out,' between Aransas and Corpus Christi Bays, the depth is six feet. This passage is about four miles long, and very narrow and crooked, but the dredging-machine in operation this season is relied upon for deepening the channel to eight feet.

"On the outside bar of Corpus Christi Pass, the depth of water is four and a half feet, but every gale of wind changes the channel, so that it is practically useless for navigation. There is, moreover, an inside bulkhead between the pass and the bay, on which the depth is but four feet."

The statistics of this survey include the tracing of thirty miles of shore-line, the erection of twenty-five signals, and the determination by horizontal angles of the positions of thirty-six objects. In hydrography, the particulars are as follows:

Miles run in sounding	639
Angles measured	2,968
Number of soundings	78,280

Sub-Assistant Anderson was aided in this section by Mr. J. N. McClintock. The party was subsequently employed in Section I.

SECTION X.

PACIFIC COAST OF CALIFORNIA, INCLUDING THE BAYS, HARBORS, AND RIVERS. (SKETCH No. 13.)

Triangulation, latitude, and azimuth near Santa Barbara, California.—Upon his return from Alaska in August, Assistant George Davidson transferred his party to the shore of the Santa Barbara Channel for the determination of the latitude and azimuth of three main stations of the triangulation of that region, and for connecting it by telegraph with the work done near San Francisco. At the date of his report, November 30, he had nearly completed the observations at station Santa Barbara.

The observations for latitude were made with the zenith-telescope No. 1, and embraced 300 observations upon 36 pairs and triplets formed by 87 stars, and 538 observations upon δ Ursæ Minoris, 51 Cephei, and λ Ursæ Minoris near elongation upon three nights for value of micrometer-screw. In the determination of the chronometer correction he observed the transits of 98 stars with the new meridian instrument of his invention, which has been described in the Report for 1867. This has a reticule of 9 threads with intervals of 10½ seconds. One hundred and twenty-three measures had been made of the thread intervals with the micrometer which is used for latitude observations.

To determine the azimuth of the lines of the main triangulation from the station Santa Barbara, Mr. Davidson set up a mark on the foot-hills north of the mission and about three miles from the station. Its position was determined from the line Santa Barbara—Hill. The mark is connected with the main lines by means of the line Santa Barbara—Pelican. At the date of his report he had observed 335 measures for azimuth upon the mark and δ Ursæ Minoris, 51 Cephei, and λ Ursæ Minoris near elongation, and 170 measures to connect the mark with the main lines and other objects; and 25 transits of stars to determine the chronometer correction.

Vertical angles were measured to determine the elevation of the mountain range behind Santa Barbara, and of stations on Santa Cruz Island.

The instrument used for the azimuth work was the 18-inch theodolite No. 4, reading by three micrometer microscopes.

Assistant Davidson computed the prediction of occultations of stars by the moon, visible at the station, and observed the immersion of 31 Sagittarii with reconnoitering telescope No. 18. Incidentally he observed the number of meteors which appeared on the 14th of November.

Mr. S. R. Throckmorton, jr., served as aid. The party of Mr. Davidson will remain in the field all winter.

Magnetic observations.—At station Santa Barbara 106 observations for magnetic declination were made by Assistant Davidson and Mr. Throckmorton upon three days, and 128 observations for horizontal intensity upon one day, with the theodolite magnetometer No. 5. For the dip, 144 observations were made by Mr. Throckmorton with three needles in three positions of the axes.

Topography of Santa Barbara Channel.—Assistant W. E. Greenwell has continued the topography of the main shore of the channel eastward from Santa Barbara toward San Buenaventura. When it reaches the latter place, the topography will be complete from Santa Barbara to Point Duma. From Santa Barbara to El Rincon the immediate coast line is settled, and the work not difficult; but thence to San Buenaventura, the mountains come abruptly to the water's edge, and reach an elevation of two thousand two hundred feet in a mile and a half. Their seaward faces are cut by very deep gorges, and the execution of the topography is very difficult. The camps are of necessity far from the scene of work, as no water fit to drink is found in a stretch of nearly twelve miles.

The condensed statistics of the season's work are:

Shore-line traced, (miles)	24
Bluff, (miles)	26½
Creeks, (miles)	39½
Roads, (miles)	55
Area embraced, (square miles)	39½

The greatest elevation over which topography has been carried in this region is two thousand one hundred and fifty-eight feet. Two sheets on a scale of $\frac{1}{10000}$ have been finished, and a third commenced. One has been partly inked. Projections for the sheets were forwarded from the office.

During the season Assistant Greenwell occupied two tertiary stations, and made the duplicates of horizontal angles from Mound Station, near Santa Barbara (see Sketch No. 3) to Point Mugu. The abstract and computation of the sides of the same have been received at the Office. A full abstract of the results was also furnished to Assistant Cordell for use in the hydrography. The party was in the field at the date of Mr. Greenwell's report, (November 15,) engaged in extending the tertiary triangulation eastward for the topography. Mr. Stehman Forney has continued in service in the party as aid.

Hydrography of the Santa Barbara Channel.—Upon completing the survey of the shoal off Point Reyes, mention of which will be made further on, Assistant Edward Cordell transferred his vessel and party to the Santa Barbara Channel. The inshore hydrography of the main coast has been carried westward from the west limit of Commodore Alden's work, two miles east of San Buenaventura, to a point forty-five miles beyond, and for seven miles in the vicinity of Point Conception, with an average width of two and a half miles. The off-shore hydrography has been carried for a distance of fifty miles, parallel with the inner work, with an avarage width of two and a quarter miles; while eight lines, comprising one hundred and sixty miles of deep-sea soundings, have been run across the channel from Anacapa Island to the west end of Santa Cruz Island, and off Point Conception. The one-hundred and two-hundred fathom curves are well developed. The deepest sounding reached was three hundred and twelve fathoms. Specimens of the bottom were obtained with each cast.

In the prosecution of this work, the triangulation and shore-line of the main and of the Santa Barbara Islands, where completed, was furnished by Assistant Greenwell; and of Point Conception by Assistant Rockwell. Assistant Cordell erected and determined the position of forty-nine hydrographic signals; and for the off-shore work determined the positions of conspicuous mountain tops on the main and islands. Tidal observations, day and night, were made from July 11 to September 16, at Santa Barbara, and from September 16 to November 7, at Santa Cruz Island.

The work of the season is comprised in seven sheets of in-shore hydrography on a scale of $\frac{1}{10000}$; with one sheet on a scale of $\frac{1}{100000}$ for the off-shore soundings.

The statistics of the channel work are:

Miles of soundings	1,278
Angles observed	6,526
Casts of the lead	19,968

Sub-Assistant G. Farquhar was attached to the hydrographic party.

Topography at Point Conception.—During the winter and spring Assistant Cleveland Rockwell, after inking and tracing his maps of the previous season, commenced the topography at Point Conception to carry it northward. Much difficulty and delay were experienced in effecting a landing at El Coxo at that season. In addition to the usual margin for shore topography he was instructed to make a survey to embrace the crest line of the Coast mountains, immediately behind Point Conception light, as seen from seaward. This was done on a scale of $\frac{1}{30000}$, with contours of 100 feet, and broad generalizations of topography in a rough but characteristic region.

The topography was based upon a tertiary triangulation made by the party of Mr. Rockwell, after the measurement of a base-line of one thousand five hundred meters, and embraced the following statistics:

Miles of ocean shore	11
Area, (square miles)	9

The statistics of the triangulation are:

Signals erected and stations marked	7
Stations occupied	8
Objects observed upon	45
Angles measured	49
Number of observations	560

Mr. Rockwell also furnished the data of his triangulation and tracing of his topography to Assistant Cordell for the hydrography. Sub-Assistant L. A. Sengteller was attached to the party.

In May Assistant Rockwell discharged his party in San Francisco, and supervised the repairs upon the schooner Humboldt, while Mr. Sengteller inked and traced the two sheets of the winter's work. The party was subsequently engaged on the shores of the Columbia River in Section XI.

Hydrography of Coxo Harbor, California.—This work was prosecuted and completed in October by Assistant Cordell, with his party, in the schooner Marcy. The soundings were carried about four miles to the eastward of Point Conception light-house (Sketch No. 13) and about half a mile to the northward and westward of it. Several attempts to extend the work further in that direction were unsuccessful on account of very strong winds and rough seas.

Harleck Castle Rock.—At the close of the season's work in the Santa Barbara Channel, Assistant Cordell was directed to search for the unknown sunken rock upon which the British bark Harleck Castle was lost; and which was reported to have 14 feet of water upon it at high water, and to lie three miles off shore and five miles northwest of Piedras Blancas. He was successful in his search and identified the rock by the mast of the vessel showing above water. The rock is bare at low water, lies inside the outer edge of the kelp-line, and in a bight of the shore between Piedras Blancas and Rio Cruzo. It is nearly one mile off shore, but inside the line of the above positions, and not in a vessel's track.

Hydrography off the South Farallon.—In November of last year Assistant Cordell was instructed to search for the reported sunken rocks about eighty miles to the southwestward of the South Farallon light. He made a projection and conducted the first search in the Coast Survey schooner Marcy in December, 1868. Subsequently Assistant Davidson had the United States revenue-cutters Lincoln and Wyanda placed at his disposal by the kindness of General John F. Miller, collector of San Francisco. The last examinations were made with every facility and advantage that could be extended by the officers in charge of the vessels. In the several examinations an area of nearly two thousand five hundred square miles was traversed, and no bottom could be found with soundings of one hundred to two hundred fathoms, nor any indication of shoal water. If the rocks exist, they must, in the opinion of Assistant Davidson, be sharp peaks. The area examined lies between latitude 36° 30′ and 37° 20′ and longitude 123° 33′ and 124° 40′.

From March 20 to June 28 Mr. Cordell attended to the repairs of the schooner Marcy, and under his direction Sub-Assistant Farquhar made three projections on a scale of $\frac{1}{100000}$, embracing the coast from Point Conception to San Diego and the Santa Barbara Islands. The topography and triangulation of previous years was plotted thereon. Mr. Farquhar also made seven projections, on a scale of $\frac{1}{10000}$, for the in-shore hydrography of the Santa Barbara Channel.

Topography of San Francisco Peninsula.—During the winter and spring Assistant A. F. Rodgers was engaged in inking and tracing the large sheet, exhibiting, on a scale of $\frac{1}{10000}$, one hundred square miles of the peninsula of San Francisco, lying between the bay and ocean. The sheet has been received at the Office, and a tracing furnished to General B. S. Alexander, Corps of Engineers, United States Army. In this work Mr. Rodgers was assisted by Mr. E. F. Dickins, temporary aid. The details relating to the survey have been given in previous annual reports.

Longitude of San Francisco, California.—To Assistant Davidson was assigned the charge of the operations on the Pacific coast for the determination of the difference of longitude by telegraph between Cambridge Observatory and San Francisco. After obtaining permission from the mayor and supervisors of San Francisco, he set up a temporary observatory in Washington Square, to which the Western Union Telegraph Company kindly ran a loop of one of their main lines. The season was favorable and the lines when used were found in excellent condition.

In this work observations over the line were commenced on the 15th of February and closed on the 4th of April. Through-signals each way were exchanged with Cambridge upon twelve nights, and directly with Omaha on eight nights, and with Salt Lake on twelve nights. The clock correction was determined by transits of Nautical Almanac and Cambridge Catalogue stars, by the electric method over a reticule of twenty-five threads. Observations were made upon several nights for this purpose. Toward the close of the experiments, and subsequent to them, Mr. Davidson, assisted by the chiefs of the other telegraph parties, made his experiments for determining

the time of transmission of the clock-signals through the double line of seven thousand two hundred miles length, composed of thirteen circuits, between Cambridge and San Francisco. At his request this double line was very liberally placed at the service of the Coast Survey on one night of each week. The experiments were successful; the San Francisco clock-signal passing through Cambridge back to San Francisco, and being there recorded by a special recording-pen upon the same register alongside the clock-pen. They were repeated upon four nights; and upon three nights similar experiments were made through Buffalo, Chicago, Cheyenne, Omaha, Salt Lake, and Virginia City. Successful experiments were also made upon one night for determining the time of transmission over a single wire. Abstracts exhibiting the working condition upon the nights of these experiments have been received. Assistant Dean, who had charge of the operations at Salt Lake, visited San Francisco, and observed with Mr. Davidson for personal equation upon sixty stars on three nights. The astronomical station was connected by triangles with the triangulation station on Telegraph Hill by Assistant Davidson, and the reductions have been computed. All the records have been duplicated as usual. The instruments used were the Kessels clock, transit No. 3, and the Hipp chronograph. A special report of the working of that chronograph has been received at the Office. Mr. Davidson was aided by Mr. Throckmorton. Liberal assistance was extended for the party operations by General Stager and the other officers of the Western Union Telegraph Company, and by George H. Mumford, esq., general agent at San Francisco.

Longitude and latitude of Salt Lake City, Utah Territory.—The astronomical station at Salt Lake City was established under the direction of Assistant George W. Dean, near the southeast corner of Temple Block, and observations for adjusting the instruments were made on the 25th of January. Sub-Assistant F. H. Agnew was attached to the astronomical party.

Unfavorable weather prevented the exchange of clock-signals for longitude determinations until the 7th of February, but from that date the work was carried forward to completion on the 3d of March. Operations at Cambridge, Massachusetts, connected with the work at Omaha and Salt Lake City, have been referred to in Section I. Signals were well exchanged between Salt Lake City and Cambridge Observatory on eight nights between the dates just mentioned. Eleven nights favorable for signals, employed the observers at Omaha and Salt Lake City. Mr. Dean exchanged time signals on ten nights with Assistant Davidson, who was stationed at San Francisco; and for the relative longitude of Brigham City in Utah signals were made and received at Salt Lake, at the request of Major J. Blickensderfer, civil engineer, one of the Pacific Railroad commissioners.

In addition to the usual processes for longitude, experimental signals were passed through the entire telegraph line on several nights from Cambridge to San Francisco, and returned through another circuit. This complex telegraph line was more than seven thousand miles in length, and the success of the experiments is highly creditable to the managers of the Western Union Telegraph Company. Acknowledgments are due for the able co-operation of the company at each of the stations occupied for longitude.

The experimental signals alluded to were made for the purpose of obtaining an approximate measurement of the time required for transmitting signals through a large number of "telegraph repeaters," adjusted in circuits from four to five hundred miles in length, and are quite different in character from experiments for the special object of determining the velocity of the galvanic wave through different kinds of conductors.

At Salt Lake City, Assistant Dean had in use a break-circuit chronometer made by Charles Frodsham, esq., of London, and reports favorably in regard to its performance.

In ascertaining the clock and instrumental corrections, Mr. Dean and Sub-Assistant Agnew recorded three hundred and ten observations on seventy-three circumpolar and zenith stars. The 46-inch transit C. S. No. 4 was used in this service.

The latitude of the station at Salt Lake City was determined by Mr. Agnew with the zenith telescope No. 6. Two hundred and forty observations were made on thirty-nine pairs of stars. The micrometer divisions were measured by two hundred and forty observations upon Polaris near western elongation; and one hundred and seven readings were noted while determining the level divisions from measurements with the micrometer.

A meridian line about a mile and a half in length was marked by Mr. Dean at Salt Lake City. The south end at which the transit pier was left is marked by a copper bolt inserted in the stone.

About two thousand feet north of the station occupied by the astronomical party, a sandstone post was sunk four feet into the ground. In its top a copper bolt was inserted, to indicate the continuation of the meridian line, the north end of which was marked simply by a cedar post sunk three feet in the ground. A copper nail in the top of the post ranges with the two copper bolts before mentioned.

The gratifying success which has attended the operations for connecting in longitude the surveys on the Atlantic with those on the Pacific coast of the United States is due in a large measure to important collateral aid; Assistant Dean makes special mention of valuable services accepted from Generals Thomas T. Eckert and Anson Stager, and from Colonel James Gamble, superintendents of the telegraph lines. The president of the Union Pacific Railroad Company, Hon. Oliver Ames, arranged for the transportation, free of charge, of the party of Assistant Dean, with instruments and equipments, from Omaha to the western terminus of the Union Pacific Railroad. To Governor Leland Stamford, president of the Central Pacific Railroad, thanks are due for transportation facilities given to the party.

By order of the Quartermaster General United States Army, teams were in readiness, and took Mr. Dean's party from the railroad station to Salt Lake City. This important assistance, received in the severity of winter, was made more acceptable by the forethought and kindness of Lieutenant Colonel W. H. Lewis, United States Army, commander of the military post near Salt Lake.

Ex-Governor Young of Utah evinced much interest in the success of the intended observations. Men and teams were sent sixty miles in mid-winter to procure suitable sandstone blocks for the large astronomical instruments. He defrayed also the expenses attending the erection of the astronomical observatory at Salt Lake City.

Magnetic observations at Salt Lake City.—The magnetic declination was determined at three stations within the Temple Square by observations on seven days. Three sets of vibrations and deflections of the magnet were made for determining the intensity; and three sets with two needles were made in ascertaining the magnetic dip. The observations were made jointly by Mr. Dean and Mr. Agnew.

When the operations at Salt Lake City, comprised in the plan made at the outset of the season, were completed, Assistant Dean proceeded to San Francisco, and there made a series of observations with Assistant Davidson for ascertaining their personal equation as observers. After his return to the Atlantic side, Mr. Dean engaged in astronomical duty in Section VII. In November he sailed for Brest to determine the difference of longitude between a station in that city and a station at Duxbury, on the coast of Massachusetts.

Light-house site at Point Reyes.—At the request of the Light-House Board, Assistant Davidson was instructed to examine Point Reyes and report upon the feasibility of a more favorable position for a light-house than that selected some years since. He visited the locality in June, accompanied by Assistants Cordell and Rodgers, and reported upon a site which was jointly considered the most eligible. Messrs. Davidson, Rodgers, and Cordell have commanded Coast Survey vessels for years upon this coast, and are familiar with the requirements of the usual aids to navigation. Their report has been communicated to the Light-House Board. Assistant Davidson is now preparing a report upon the fogs of the Pacific Coast and the peculiar requirements in respect of light-houses and other aids to navigation.

Shoal off Point Reyes, California.—A shoal known to exist some miles to the westward of Point Reyes, and of which mention was made in the first edition of the Directory for the Pacific Coast, published in 1858, has been developed by Assistant Cordell. Assistant Davidson made a cast of thirty fathoms in that vicinity as early as the year 1853, in passing to San Francisco from the northward. In the formal search attention was first drawn to the special site of the shoal by numbers of seal, sea-lions, and marine birds, which resort there. In describing the result of his soundings, Mr. Cordell says: "The least water found was twenty-five fathoms, about one mile S. E. ½ E. from the central point of the shoal. The shoal is five miles long, with an average width of a mile and a quarter, within the curve of thirty fathoms; but it is twelve miles long and five miles wide within the fifty-fathom curve. Its longest axis is in a direction N. W. and S. E., or nearly in the prolongation of a line through the Farallon Islands."

"Sounding within the thirty-fathom curve, the lead failed to bring up specimens of bottom, it proving to be rocky. The lead was then armed, and live barnacles were brought up. Outside of this curve there is a deposit of white shells, broken fine. Beyond the depth of forty fathoms we found coarse black sand mixed with gravel and broken shells."

"The general set of current, as observed, was in a southerly direction, with a velocity of about one to one and a half knots per hour."

"Reference to the chart shows that the water gradually deepens from the shoal toward the mainland, attaining a depth of 70 fathoms, after which it shoals again toward the shore."

"A barrel-buoy painted black, with white and black flag, was placed in the shoalest water found, to identify the position while sounding, and was left 'watching' when the schooner Marcy returned to San Francisco, on the 30th of June."

Latitude of buoy	38° 01′ N.
Longitude of buoy	123° 26′ 30″ W.

South Farallon light-house bears from the buoy or shoal E. S. E. magnetic, distance twenty-nine nautical miles. West head (Point Reyes) bears from the shoal E. by N., distance twenty-one nautical miles.

The particulars here recited were made known at once through the daily newspapers of San Francisco, for the benefit of mariners, and were also published in the usual form of notice from the Coast Survey Office.

It is probable that depths of less than twenty-five fathoms may yet be found within the limits of this shoal. Attention will be given incidentally for its further development, because of its importance to vessels coming from the northward in thick weather. A change of swell is readily perceived upon the shoal.

Latitude, longitude, and triangulation at Humboldt Bay and Cape Mendocino.—In April Assistant Davidson determined the latitude, longitude, and elevation of Cape Mendocino light. After the determination of their corrections at San Francisco, he carried twelve chronometers to Eureka, Humboldt Bay, occupied a secondary astronomical station there, and connected it with the work of 1854. Finding the roads very bad, four of the chronometers were sent to Cape Mendocino by water. There twenty-four transits of stars were observed upon two nights, and twelve pairs of stars for latitude, with zenith telescope No. 1. Transit No. 9 was used in the observations. A small triangulation was made to connect the astronomical station with the light-house, the elevation of the latter was determined, and the position of Blunt's Reef. Bearings were also taken upon six sunken rocks in the channel, between the reef and the cape. At Eureka the station was again occupied, and transits observed upon one night. Transits were observed upon two nights after the return to San Francisco. Mr. Davidson reduced his latitude observations, and part of the longitude observations, for an approximate position of the light, which information, with the ascertained elevation of the light, has been communicated for the use of the Light-House Board.

Mr. Davidson's visit to Mendocino was also made effective in settling on the best plan for developing the triangulation and topography along that part of the coast of California.

Reconnaissance and survey of the vicinity of Cape Mendocino, California.—Early in May, Assistant A. F. Rodgers visited Cape Mendocino with a view of obtaining such information as could best be had from personal observation, with reference to the facilities for conducting the survey of that part of the coast of California. After reaching Noyo River, he proceeded to the cape on horseback, extending his journey to Eel River and Humboldt Bay. At Eel River Entrance the water was breaking badly from the beaches, so that it was impracticable to attempt to pass the bar. Local information, and the observations made by Mr. Rodgers, lead to the belief that the bar at Eel River is a shifting one. At Eureka, on Humboldt Bay, Assistant Rodgers made such arrangements as would be needful for the transportation of his party and instruments from that place to Cape Mendocino. His party, which was organized immediately after his return to San Francisco, reached Eureka in the latter part of June. He has since connected the triangulation and topography of Humboldt Bay, executed in 1854, with Cape Mendocino, determined the position of Blunt's Reef, and made a hydrographic survey of Eel River from the entrance to a point three miles inside. This work has special importance, as bearing upon the question of the feasibility of

getting the lumber of that valley directly to a market. The triangulation is connected with the astronomical stations of Assistant Davidson at Cape Mendocino, Humboldt, Eureka, and Bucksport.

In the execution of the triangulation, the following statistics are reported:

Signals erected	32
Stations occupied	31
Angles observed	246
Observations	700
Area covered by triangulation, (square miles)	93

Incidentally, observations were made upon the high peaks, Mount Pierce and adjacent mountains, as they are frequently visible from seaward when the immediate shores are not. The instrument used was an eight-inch repeating theodolite. The topography is included in four plane-table sheets; showing the coast from the entrance of Humboldt Bay to Cape Mendocino. The former was re-surveyed on account of extensive changes since the previous survey. The following statistics are reported:

Shore-line of ocean, (miles)	28
Creeks, including Eel River, &c., (miles)	46½
Area, (square miles)	39

The topography and triangulation have been carried to elevations of nearly two thousand five hundred feet.

The hydrography was incidental to the regular work of the party, and included ten miles of soundings and nine hundred and ninety-two casts of the lead.

During part of the season, which closed on the 11th of November, Mr. Rodgers was aided by Mr. A. P. Redding. The plane-table sheets are now in hand for inking.

Coast reconnaissance.—Assistant Davidson has furnished a view and a description of Redding's Rock, off the coast of California, in latitude 41° 21′; and determined the position of the mammoth buoy off the entrance to Humboldt Bar.

Tidal observations.—The self-registering tide-gauge at San Diego has been kept, as heretofore, by Mr. A. Cassidy. That at Fort Point (San Francisco Entrance) was in the care of Mr. H. E. Uhrlandt until the middle of May, when he was succeeded as observer by Mr. William Knapp. The work at these stations includes meteorological records, and has been continued under the acceptable supervision of Major G. H. Elliot, of the United States Engineers.

Until he resigned, Mr. Uhrlandt continued the tabulation of the readings of high and low waters taken from the tide-rolls of the gauges operating at San Diego, Fort Point, and Astoria.

SECTION XI.

PACIFIC COAST OF OREGON AND OF WASHINGTON TERRITORY, INCLUDING THE INTERIOR BAYS, PORTS, AND RIVERS. (SKETCH NO. 15.)

Topography of Point St. George and the Dragon Rocks, California.—After completing work at Cape Orford, Sub-Assistant A. W. Chase transferred his party to Crescent City to continue the tertiary triangulation and topography northward from the limit of the work of 1859. He reached that place in September, measured a short base, and carried the triangulation and topography five miles northward of the previous work. From a fair base in this triangulation, he determined the position and elevation of all the visible rocks and breaks of the Dragon Rocks or Crescent City Reef, amounting to eighteen. He expresses the belief that a detailed hydrographic survey may reveal others.

The most northern rock of the reef is seven and a half miles from the northern part of Point St. George. Heavy weather prevented the occupation of any station on these rocks, but upon one opportunity Mr. Chase went in a whale-boat and determined in position approximately the sunken rock, locally known as the "Jonathan Rock," a mile and a half west of the main body of the reef, and two miles south of the Southwest Seal Rock.

The results of this close determination of the reef indicate a good steamer-channel, of one and a half miles in width, between Point St. George and the main body of the reef.

The statistics of work are as follows:

In the tertiary triangulation—	
Signals erected, marked, and described	14
Stations occupied	14
Angles observed	172
Number of observations	1,198
In the topography—	
Miles of shore-line	5
Area, including rocks, (square miles)	$4\frac{1}{2}$

The topography is comprised in two plane-table sheets, one, on a scale of $\frac{1}{10000}$, to include Point St. George and the main body of the rocks; the other on a scale of $\frac{1}{20000}$, to include the point and the extreme northwest rocks.

His report is accompanied by a sketch of the rocks and main shore on a scale of $\frac{1}{100000}$, and a scheme of the triangulation on the same scale.

Mr. Chase continued in the field until October 28, and then inked his sheets preparatory to resuming the topography westward of San Pedro. He was assisted throughout the season by Mr. M. Liprowitz, temporary aid.

Triangulation and topography of Cape Orford, Oregon.—During the winter, Sub-Assistant Chase was engaged in plotting and inking his work of the Yaquinna River and adjacent coast. After accompanying Assistant Davidson to Cape Mendocino, he received instructions to extend northward the tertiary triangulation and topography done in previous years at Port Orford, and to include the reef. For this he measured a base-line of five thousand three hundred and seventy-nine meters on the beach, south of Elk River and within the limits of Assistant Harrison's plane-table sheet of the former survey, and carried the tertiary triangulation ten and a half miles northward of Port Orford, and including the reef. At the main astronomical station occupied by Assistant Davidson in 1851, he observed a preliminary azimuth by an observation of Polaris at eastern elongation and referred it to a station on Cape Blanco.

The statistics of this triangulation are:

Signals erected, marked, and described	15
Stations occupied	10
Angles measured	43
Number of observations	516

Besides these there were made two hundred incidental observations to determine positions and bearings of the rocks off Coquille River and Rogue River Entrances and of prominent mountains. Theodolite No. 21 was used for this work. The topography of the reef was executed by occupation. Mr. Chase visited it several times and located forty-five rocks and breaks. Along the main shore the topography was confined to the immediate coast, as the country is too densely-wooded to permit work with a plane-table. At Cape Orford, the country being more open, the topography was carried about a mile and a half in, and special attention was paid to the locality chosen for a light-house. The results of this work were communicated, under instructions, to Colonel R. Williamson, the light-house engineer, and the thanks of the Light-House Board have been received in return.

The topography was carried to a point three and a quarter miles northward of the cape, and embraces the following statistics:

Main shore-line, (miles)	8
Trails, (miles)	5
Area, including rocks, &c., (square miles)	$6\frac{1}{2}$

The work is on two sheets on a scale of $\frac{1}{10000}$, and one sheet of reconnaissance on a scale of $\frac{1}{30000}$. Mr. Chase appended to his report a sketch, on a scale of $\frac{1}{100000}$, showing the relation of the reef and the shore; and one on the same scale exhibiting the scheme of the triangulation; also, a colored view of Cape Orford.

A preliminary examination of the steamer-channel through the reef was made; it has good depth of water and a clear width of one and three-fourths miles.

Throughout the season Mr. Chase has been assisted by Mr. M. Liprowitz, temporary aid. Upon the completion of this work the party was transferred to Crescent City.

Astronomical observations at Astor Point, Oregon.—When returning from Alaska in August, Assistant George Davidson re-occupied the triangulation and secondary astronomical station at Astor Point, on the Columbia River, and upon one night observed the transits of sixteen stars with the new meridian instrument. This station he connected in longitude with San Francisco by the transportation of sixteen chronometers. At Portland rainy weather prevented observations before the return of the steamer to San Francisco.

Topography of the Columbia River, Oregon.—The topographical survey of the Columbia River has been continued by Assistant Cleveland Rockwell, who reached this section on the 30th of July and commenced operations at Cape Disappointment. The establishment of a military post at the extremity of the cape, with its numerous improvements and changes since the survey of 1851, rendered a re-survey of that part desirable, and it was done. The work executed embraces the bold ocean headlands to the low sand beach which runs northward to Point Grenville, only broken by Shoalwater Bay and Gray's Bay Entrances. On the inner shore of the cape, forming Baker's Bay, the work was carried to Chinook, and was in progress beyond at the date of the last field-report. Sandy Island has been re-surveyed and found altogether changed in shape and position from the results of last year's examination.

The statistics of the season's work are:

Shore-line and streams, (miles)	61
Shore-line of lakes, (miles)	3½
Road and trails, (miles)	10½
Area, (square miles)	13

Mr. Rockwell reports the interior of Cape Disappointment so densely wooded and covered with undergrowth as to be impenetrable for ordinary operations with an observing instrument. The first part of the season was smoky from the great fires raging in the forests of Oregon and Washington Territory. Early rains extinguished the fires, and were succeeded by fogs. The latter part of the season was favorable. Mr. Rockwell had the use of the Coast Survey schooner Humboldt, and was accompanied by Sub-Assistant L. A. Sengteller.

Hydrography of the Columbia River, Oregon.—The condensed statistics of the hydrography of the Columbia River, commenced in November, 1867, and closed in August, 1868, were not included in my report of last year. There were 2,455 miles of soundings run, 21,282 angles observed, and 91,479 soundings made.

Between the beginning of November, 1868, and the end of May, 1869, Assistant Cordell plotted and inked the soundings on three hydrographic sheets of Columbia River from Three-Tree Point to Tongue Point, on a scale of $\frac{1}{10000}$; and on two sheets, including the bar and entrance from Cape Disappointment to Tongue Point, on a scale of $\frac{1}{20000}$. Duplicate tracings of this work were made for the Coast Survey Office, and for General B. S. Alexander, United States Corps of Engineers. A comparative chart was then drawn, showing the change in the hydrography of the approaches and entrance of the Columbia since 1854. A current-chart was also made, exhibiting the positions of seventeen current-stations in the north and south channels, and in the approaches to the main channel from the entrance of the river up to Astoria.

Duplicates of thirty-one sounding-books and ten tide-registers have been received at the Office.

Sub-Assistant G. Farquhar and Mr. A. P. Redding were on service in the hydrographic party of Mr. Cordell.

Reconnaissance on the coast of Oregon.—Assistant Davidson has furnished views and descriptions of Cape Sebastian in latitude 42° 18′; Heceta Head, in latitude 44° 09′; Cape Perpetua, in latitude 44° 19′; Cape Foulweather, in latitude 44° 52′; and the Yaquinna Pass, in latitude 44° 45′; Nekas River, in latitude 44° 56′; Cascade Head, in latitude 45° 03′; Split Rock, in latitude 47° 23′; and Sea Lion Rock, in latitude 47° 27′. These were made in July, on the voyage to Alaska.

Astronomical observations in the Straits of Fuca.—On his way to observe in Alaska the solar eclipse of August last, Assistant Davidson stopped and determined the geographical position of Esquimalt and Victoria, on Vancouver Island. Sixteen chronometers were transported to and from San Francisco.

The following are the statistics of this work:

At Esquimalt, for time and longitude, transits of fourteen stars, one night; at Victoria, for time and longitude, transits of forty-four stars, two nights. For latitude he observed difference in the zenith distances of ten pairs of stars. These observations were made in order to get additional data for the discussion of station error existing at one of the astronomical stations in this vicinity. The instrument used for time and latitude was Mr. Davidson's new meridian instrument No. 1. Assistant Davidson was aided by Mr. S. R. Throckmorton.

Under direction of Mr. Davidson the stations at Esquimalt and Victoria were trigonometrically connected by Assistant Lawson in August and September. The latter station had been previously connected with the triangulation of Washington Sound and Admiralty Inlet.

Triangulation and topography of Port Discovery, Washington Territory.—At the date of my last annual report on the progress of work in this section, Assistant J. S. Lawson had his party on the brig Fauntleroy in effective condition, and daily expected to commence the survey of Port Discovery. So dense, however, was the smoke, and so widely prevailing in this part of Washington Territory, that a boat could not be safely sent from the vessel, and, if sent, could not be distinguished at a distance of a hundred yards. Vessels, after entering the Straits of Fuca, were at that remarkable period from twelve to twenty days in reaching Port Townshend, a distance of only ninety miles. The vessel containing the party narrowly escaped being run down by a large ship, which had been set out of her course, and which was not seen until almost aboard of the Fauntleroy. The unusual calms by which the smoke became a permanent obstacle were followed by continuous stormy weather. Mr. Lawson in consequence closed field operations on the 14th of November, 1868, having had but two days on which the plane-table could be worked, after the disappearance of the smoke. All favorable hours, however, were employed in determining the positions of signals for the survey of Port Discovery. The vessel was then taken to Olympia, and, just previous to the discharge of the crew, was dismantled and moored for the winter. In office-work Mr. Lawson, and his aid, Mr. J. J. Gilbert, inked and plotted the topographical and hydrographic sheets of the survey of Port Madison, and computed results from the triangulation of Port Discovery. These, with similar computations for the triangulation last made by the party in Admiralty Inlet and Puget Sound, have been received at the Office.

The necessity for thorough repairs on the brig Fauntleroy delayed the organization of the party for work during the summer, but with no loss of time available for field operations, as a repetition of the smoky season commenced in June and continued until the first heavy rain-fall, in the latter part of August. Taking advantage of the first favorable weather for making determinations which had been postponed, the Fauntleroy was moved to Esquimalt Harbor, in tow of the United States steamer Pensacola. There the astronomical stations, occupied by Assistant Davidson in July of the present season, were connected by Assistant Lawson with the triangulation of the Straits of Fuca. Mr. Davidson reviewed this work on his return from Alaska, and then passed on to San Francisco, where he subsequently received the field computations.

After returning to Port Discovery, the plane-table survey was continued by Mr. Lawson and his party. Two topographical sheets have been completed; the first extending from Rose Signal to Fog Signal, (see Sketch No. 15,) including Protection Island and the entrance, and the other the middle part of Port Discovery.

The statistics of triangulation and plane-table work are as follows:

Signals erected	22
Stations occupied	14
Angles measured	44
Number of observations	1,184
Shore-line surveyed, (miles)	11

During the last two years but little rain has fallen, comparatively, in this part of Washington Territory, and hence the fires started in pine forests have enveloped hundreds of square miles in smoke.

Tidal observations.—The self-registering tide-gauge at Astoria, on the coast of Oregon, has been in the care of Mr. L. Wilson, who has maintained the series well, as also the elaborate record of meteorological observations. This station and the two permanent stations on the coast of California are under the supervision of Major Elliot, of the United States Engineers.

SECTION XII.

PACIFIC COAST—ALASKA TERRITORY. (SKETCH No. 16.)

Solar eclipse of August 7 in Alaska Territory.—While on the way with his party to observe the solar eclipse on the time of totality in Alaska, Assistant George Davidson determined the geographical position of Fort Wrangel near the mouth of the Stakeen River; of Kootznow and Nauœtghughos, in Chatham Strait; and finally of the eclipse station Kohklux, in the village of Kobkaghtoo, on the Chilkaht River.

The time and longitude were determined with the new meridian instrument invented by Mr. Davidson, and by sixteen chronometers transported from and to San Francisco.

The number of observations were as follows:

At Fort Wrangel, for time, double altitudes of the sun	15
At Fort Wrangel, for time, transits of stars	20
At Fort Wrangel, for latitude, pairs of stars	11

The usual preliminary measures were made for value of the micrometer of the meridian instrument:

At Kootznow, for latitude, circum-meridian altitudes of the sun	3
At Nauœtghughos, for time, double altitudes of the sun	25
At Sitka, for time, transits of stars upon 6 nights	46
At Sitka, for time, double altitudes of sun	18
At Sitka, for latitude, pairs of stars	7

And at Sitka he connected the work of this season with that of 1867, and re-determined the elevation of the extinct volcano Mount Edgecumbe.

At Kohklux, for time, double altitudes of the sun	25
At Kohklux, for time, transits of stars, 5 nights	42
At Kohklux, for latitude, pairs of stars	12

The observations were all made by Mr. Davidson, aided by Mr. S. R. Throckmorton, jr. Duplicates of the records and the originals have been received at the Office.

Assistant Davidson's report on the eclipse expedition, and upon the phenomena of the totality at station Kohklux, in latitude 59° 24′, will be found in the Appendix, No. 8. Owing to frequent clouds, the beginning of the total phase only was successfully observed.

Mr. Davidson computed the predictions for all the occultations of stars by the moon during the expedition to Alaska, but unfavorable weather prevented their observation. He re-computed for his station on the Chilkaht River the prediction of the solar eclipse; reduced the latitude observations made at Sitka, Kohklux, and Fort Wrangel; and computed results from the magnetic observations at Kohklux.

Regular comparisons of the sixteen chronometers were made by coincidences of beats. Six navy chronometers were kindly lent for this expedition by Lieutenant Commander E. C. Merriman, United States Navy, navigation officer at Mare Island, California.

Mr. Davidson states that the work in Alaska was done under many difficulties. From Sitka his party went with an open boat and a canoe through the great straits. The country was full of hostile and warlike Indians, but the party was treated with great kindness. General Jeff. C. Davis, at Sitka, commanding the Military Department of Alaska, furnished Mr. Davidson with a boat and extended every facility to aid his party. General George H. Thomas gave orders for transportation in the United States quartermaster's steamer Newbern from San Francisco to Sitka. By invitation of Hon. William H. Seward, who visited the camp of Assistant Davidson on the Chilkaht, the party returned to San Francisco in the North Pacific Transportation Company's

steamer Active. The assistance received from Captains Freeman and Dall, of those steamers, is specially mentioned in the field-report. Before leaving the Territory, Assistant Davidson incidentally made a vocabulary of three hundred and fifty words of the language of the Chilkaht Indians.

Magnetic observations.—Observations for the magnetic declination, horizontal intensity, and dip were made by Assistant Davidson at the eclipse station Kohklux, on the Chilkaht River.

For declination upon 3 days	92 obs'ns.
For horizontal intensity upon 2 days	166 "
For horizontal intensity upon 1 day	32 "

The effect of the magnetic-iron ore in the soil and in the mountain range overhanging the river was to cause a local deviation of 10° from the calculated declination. Mr. Davidson traced for twenty-five miles a mountain ridge of two thousand feet in height, which he found to be composed of magnetic ore, some of which would yield 72 per cent. of iron. He also found iron on the shore of Chatham Strait.

Reconnaissances in Alexander Archipelago, Alaska.—At Etoline Harbor, (Fort Wrangel,) and extending as far as Point Highfield, Mr. Throckmorton made, under the direction of Assistant Davidson, a reconnaissance, with soundings, to exhibit the best anchorage. Lindenberg Cove, in Peril Strait, was sketched and sounded for the same purpose, and also the vicinity of the beach on which the party encamped, in latitude 58° 50′, on the west shore of Chatham Strait.

Mr. Davidson sketched several parts of the coast before leaving Alaska. His views include Etoline Harbor; Dall's Head, on the east shore of Clarence Strait; the passages leading to Fort Tongas, through a course of eight miles; and the Kootznow Rapids, leading from Chatham Strait to the coal deposits on Admiralty Island, a distance of seven miles. These sketches are now at the Office, and also a chart sent by Mr. Davidson to exhibit corrections which he had been enabled to make in the best existing charts of the Alexander Archipelago.

Tidal observations.—Assistant Davidson, before leaving the coast of Alaska in 1867, established several tidal stations. In the course of this year the records of partial series have been received at the Office, the latest being from the tide-gauge at Sitka, in August and September of the present year. One of the series, continuous for nearly seven months of 1867–'68, was recorded at the station estalished by Mr. Davidson at Unalaska.

COAST SURVEY OFFICE.

The general direction of the operations in the Office of the Coast Survey, where the surveys made by the field-parties are combined into charts and published, has remained, as heretofore, with Assistant J. E. Hilgard. The operations of the Office are made to keep pace with the field-work; the results of each season are fully elaborated within the subsequent year, and all accumulation of back work is thus avoided, except so far as the completion of the survey over more extended areas affords the data for comprehensive adjustments of geodetic reeults, and for charts of a general character. The operations of the past year are briefly stated below:

Computing division.—The work of this division, comprising the computation of all triangulation of observations for latitude and azimuth, as well as of magnetic observations, has been, as heretofore, under the immediate charge of Assistant C. A. Schott, with the same force of computers as employed during the previous year, consisting of Messrs. T. W. Werner, James Main, G. Rumpf, and E. Courtenay; the distribution of the different classes of work remaining unchanged. In addition to the special duties as chief of the computing division, Assistant Schott continued the monthly magnetic observations until June, when the series was concluded. His general report on this work and the discussion of its results are given in Appendix No. 9. During the months of July, August, and September much of Mr. Schott's time was given to preparing the instrumental outfit for the solar-eclipse observations, in which he participated, and on which he has prepared an elaborate report, contained in Appendix No. 8. He also contributes to this volume a report (Appendix No. 6) on the adjustment of the primary triangulation on Chesapeake Bay, which is in continuation of former papers of a similar nature, connecting together a continuous triangulation from

Quoddy Head to Cape Henry. The comparison of the different base-lines that have been measured at intervals in this long series of triangles, given in the report referred to, will be found of special interest, as affording the surest and most obvious test of the precision with which the survey has been conducted.

Tidal division.—The inspection of the tidal and meteorological observations when received at the Office, the correspondence with the observers, the supervision of the computations, and other works relating to tides and tide-gauges, have been kept up by Mr. R. S. Avery, assisted by Mr. A. Gottheil, Mr. J. Downes, and Miss M. Thomas. All data and other information respecting tides required for Office use, for observers, and for the use of field-parties, have also been furnished. The ordinary reductions of the observations, and deduction therefrom of the general results used for charts and other purposes, have been made as soon after the observations were received as practicable. The tide-tables, or predictions, for 1870, the fourth year of the series, have been computed in this division and are published. They contain the approximate predicted times and heights of the tides for about twenty of the most important places on our coasts, with tables of constants for finding from them the tides for a great number of other places. They are improved each year as the accumulation of new materials and the extension of the discussion of them render it possible.

Hydrographic division.—The drawing and verification of hydrographic charts from the original notes of soundings and angles, the verification of charts reduced to the scales of publication, the preparation of sailing directions and all notes pertaining to navigation, have been, as heretofore, performed in this division of the Office, under the immediate direction of Captain C. P. Patterson, inspector of hydrography, by Mr. E. Willenbücher, assisted by Mr. J. Sprandel.

Drawing division.—In the conduct of this branch of the Office the assistant in charge has been ably seconded by Mr. W. T. Bright, who has had charge of the details of the division, and has materially assisted in planning the work. The drawings for engraved charts have been made by Mr. A. Lindenkohl, chief draughtsman, and by Messrs. H. Lindenkohl, L. Karcher, and F. Fairfax. Traced copies of maps have been made by W. Fairfax and B. Hooe. Views of headlands and approaches to harbors have been taken during the year by Mr. W. McMurtrie, and were afterward drawn by him for engraving on the charts. Copies of manuscript maps and charts, or portions of such, are frequently furnished, upon request, to other branches of the public service, as well as to private persons; the latter, of course, paying for the cost thereof. This is an important form in which the information collected by the Coast Survey becomes available to the public, and a list of the maps so furnished during the year is given in Appendix No. 2. A list of the maps and charts, either wholly drawn during the year, or the work on which has been continued as far as the material on hand permitted, together with the names of the persons engaged upon them, is given in Appendix No. 3.

In addition to the work shown in that table, the following statement will serve more fully to exhibit the operations of the division:

Projects for new charts prepared	10
Tracings made on special calls	82
Projections made for field-maps	54
Projections made on copper for engraved charts	7
Miscellaneous tracings and diagrams for field and Office use	67
Views drawn for engraving on charts	19
Topographical sheets traced for reduction by photography	9

Engraving division.—In this important branch of the Office, under the immediate direction of Assistant E. Hergesheimer, the progress has been very satisfactory. In submitting his annual report Mr. Hergesheimer says:

"I have continued during the year experiments looking to a reduction of the cost of some heretofore tedious and expensive operations of engraving, as well as to furnish the means for the production of a class of maps fair in finish and graphic effect, and complete as to fact, by which we may publish, in much less time than heretofore, the results of our surveys.

"The success of the pantograph in reducing outlines directly upon the plate, from tracings of the original surveys, opened the way for the disposal of the topographical part of the work and led

to the consideration of mechanical means for completing the necessary topographical details. Etching had proved so successful and rapid a mode for engraving woods that I deemed no experiment in that direction necessary, but endeavored to so improve the combination of the roulette and ruling-machine as to dispose in a rapid manner of the broad surface of grass occupying so much time when engraved by hand.

"I found in the roulette heretofore used the axis of revolution shorter than the diameter of the wheel, consequently any wear or play of the axis was multiplied on the surface of the wheel, tending to interrupt the parallelism of the ruled lines. I had a variety of roulettes made with axis of revolution about three times the length of the diameter of the wheel, by which means all play in the bearings was reduced to one-third upon the circumference of the wheel. The old roulettes had the ends of the axis turned to conical points, which fit into corresponding sockets in the arms of the carriage. This I reversed, in order to retain permanently, as a center of revolution, the center upon which the wheel was turned in the lathe, having adjustable conical steel points in the carriage fitting the sockets in the ends of the axis. By this means there is preserved a revolution of the wheel in a plane perpendicular to the axis, except so far as it may be affected by a wear of the bearings. Special care was taken to make the teeth of the roulette as long as possible in order to secure deep work. The result appears in the tinting of the land of New York Entrance, which I have had the pleasure to lay before you.

"My attention was next directed to the application of the same means to the sand tinting of the six, twelve, and eighteen feet sections of the bottom. This was only a question of mechanical skill in the construction of the roulette, with such modifications of the diameter for different openness of dot as readily suggested themselves. Mr. Charles W. Black, under my direction, succeeded in making a series of roulettes, which were used for the sand of Galveston Entrance, New York Entrance, and Port of New Berne, the edges of the sections only being done by hand. Thirty-six ounces weight has been used on these roulettes without any perceptible injury to them, and I am satisfied that double that weight can be used should a tint require it.

"The work on the maps named was done at less than one-fifth the cost it would have required to do it by hand in the most inferior manner. Although I hope for still better results, enough has already been reached, I think, to congratulate ourselves on a considerable stride toward success.

"The former mode of engraving buoys, by which the sign, name, color, and number were all engraved, required a considerable amount of work, and often, in narrow channels, interfered with soundings and other features important to navigation. I therefore, in the early part of the year, proposed a system of signs, by which all the characteristics of the buoy, except the number, are at once distinctly indicated, which, with some modification in form by yourself, has been adopted.

"The Light-House Establishment uses four kind of buoys as follows:

"1st. Red—to be left in entering on starboard hand.

"2d. Black—to be left in entering on port hand.

"3d. Black and red horizontal stripes—danger-buoy.

"4th. Black and white perpendicular stripes—channel-buoy.

"Our new system gives an open white sign for a red buoy; the same sign in black for a black buoy; the open sign with a horizontal black bar for a danger-buoy, and the open sign with vertical black bar for a channel-buoy. The number, being engraved below each buoy, completes the information connected with it.

"Coast Chart No. 9 (Boston Bay) was the first chart to which the new system was applied, on which the buoys will be found to have a distinctness which the old system could not give."

The force of engravers has remained the same as for several years past, viz: Letter-engravers, Messrs. J. Knight, E. A. Maedel, A. Petersen; topographical engravers, J. Enthoffer, H. Evans, A. Rolle, A. Sengteller, A. M. Maedel; miscellaneous engravers, H. S. Barnard, J. C. Kondrup, R. F. Bartle, W. A. Thompson, J. G. Thompson, F. W. Benner, E. H. Sipe. The pantograph was used by Mr. E. Molkow. Mr. G. W. Morrison acted as writer in the division. Appendix No. 4 gives in detail the charts worked upon, and the class of work performed on each chart by the several engravers.

The *electrotyping* and *photographing* operations have been continued by Mr. George Mathiot, assisted by F. Ober. Thirty-three electrotype copper-plates, mostly of the largest class, having

between 900 and 1,500 square inches surface, have been made during the year, part of which are *altos*, or relief-plates, from engraved plates; part *bassos*, or printing-plates.

The photographic reductions required for the use of the drawing and engraving divisions have been made as heretofore.

Division of charts and instruments.—The work in this division, which includes, besides the safe-keeping of archives, the map printing, distribution of charts and reports, and the mechanicians' and carpenter shops, has been directed during the year by Mr. J. T. Hoover.

The duty of registering and filing for convenient reference the original maps and charts of the survey, and the records of observations made in the field, and of keeping an account of the same, as they are used in the Office, has been performed by Mr. A. Zumbrock.

By the press used for copper-plate printing, 7,215 copies of charts and sketches have been printed within the year. The copper-plate press has been worked as heretofore by Mr. T. V. Durham.

The work of backing with muslin the sheets required by field and hydrographic parties, and the miscellaneous duties pertaining to the folding-room, were performed during the year by Mr. H Nissen.

The map-room was in the care of Mr. T. McDonnell. An aggregate of 12,843 copies of charts has been issued within the year, and 2,247 copies of Annual Reports of various years have been distributed.

The work in the instrument-shop was done, under the supervision of Mr. William Wurdemann, by J. Foller, C. W. Black, William Jacobi, and apprentices M. F. Keys and E. Eshelman.

The wood-work of instruments, their packing for transportation, the construction of cases for maps and copper-plates, and all work of carpentry required in the Office has been performed by Mr. A. Yeatman, assisted by Mr. F. E. Lackey.

Mr. V. E. King has, as heretofore, efficiently performed the duties of chief clerk of the Office having charge of the general correspondence and Office accounts, assisted by Mr. W. H. Davis as writer. Mr. T. Emory acted as writer in the hydrographic division.

In the office of the general disbursing agent of the Coast Survey, Samuel Hein, esq., the duties of principal accountant and book-keeper have been discharged with great promptness and dispatch by Mr. R. L. Hawkins during the past as during many previous years; Mr. W. A. Herbert acting as writer.

Professional papers.—The appendix contains, in addition to the several reports mentioned in the preceding pages, the following papers on subjects connected with the work of the Coast Survey:

Appendix No. 5 is an essay *on the reclamation of tide-lands*, by Assistant Henry Mitchell, who is specially charged with the subject of physical hydrography.

Appendix No. 7 gives an investigation by Assistant C. A. Schott of the *local deflections of the plumb-line* in the vicinity of Washington.

Appendix No. 12 is an exposition of the use of the *zenith telescope for observation of time*; and

Appendix No. 13, a discussion of the depth of the Pacific Ocean, from earthquake waves in 1868, both by Assistant J. E. Hilgard.

Appendix No. 14 gives a solution of the *three-point problem*, with its application to the plane-table, by A. Lindenkohl.

CONCLUSION.

In concluding this report, I rejoice to bear testimony to the zeal and loyalty with which the officers of the survey have sustained me in carrying on the operations of the year. The just pride which the assistants manifest in the successful prosecution of the work, and their harmonious co-öperation, are sure pledges of their integrity and of their fidelity to public interests.

The hydrographic inspector, Captain C. P. Patterson, has not merely discharged the duties of his office with the skill to be expected from his abilities and experience. He has taken an intelligent interest in all the operations of the survey, and has been ready everywhere with fertile suggestions for the good of the service.

My acknowledgments are gladly extended to the assistant in charge of the Office, J. E. Hilgard, esq., whose profound scientific acumen and extensive research, permit no opportunities to escape for making improvements in the executive branches of the work.

The arduous duties of disbursing agent for the survey have been discharged by Samuel Hein, esq., with undeviating precision; and by Assistant W. W. Cooper, in the discharge of clerical duties, I have been spared from the most laborious of the details of administration.

Respectfully submitted.

BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

Hon. GEORGE S. BOUTWELL,
Secretary of the Treasury.

APPENDIX.

APPENDIX No. 1.

Distribution of surveying parties upon the Atlantic, Gulf, and Pacific coasts of the United States during the surveying season of 1868–'69.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION I.				
Atlantic coast of Maine, New Hampshire, Massachusetts, and Rhode Island, including seaports, bays, and rivers.	No. 1	Topography	W. H. Dennis, assistant; O. H. Tittmann, aid.	Topography of the banks of the St. Croix River above and below Calais, Me. Examination of the vicinity of De Monts Island, in St. Croix River, for light-house purposes. (See also Section V.)
	2	Hydrography	Charles Junken, assistant; G. W. Bissell and W. I. Vinal, aids.	Hydrography of Hurricane Sound and approaches, (Penobscot Bay,) and soundings developing the middle part of Isle au Haut Bay, Me. Examination of Prospect Harbor. (See also Section II.)
	3	Hydrography	F. P. Webber, assistant; F. D. Granger, sub-assistant; R. B. Palfrey, aid.	Soundings in Penobscot Bay, connecting the hydrography about the Fox Islands with the surveys of Camden and Rockland Harbors. (See also Section VIII.)
	4	Hydrographic reconnaissance.	J. S. Bradford, assistant; L. B. Wright, aid.	Examination of the coast and harbors between Penobscot Entrance and Boston, and compilation of a general coast pilot. Special examination at Salem Harbor and at Scituate for the Light-House Board. (See also Section IV.)
	5	Topography	F. W. Dorr, assistant; H. M. De Wees, sub-assistant; George C. Schaeffer, jr., aid.	Topographical survey of the lower part of Georges River, Me., and of the islands lying off the entrance. (See also Sections IV and VII.)
	6	Topography	W. H. Dennis, assistant; O. H. Tittmann, aid.	Plane-table survey completing topographical details of the vicinity of South Thomaston, Me. (See also Section V.)
	7	Topography	Charles Hosmer, assistant	Supplementary details completing the plane-table survey near Thomaston, Me. (See also Sections II and V.)
	8	Topography and hydrography.	C. H. Boyd, assistant; Jos. Hergesheimer and J. G. Spaulding, aids.	Topography and hydrography of the Kennebec River, Me., extended from Merrymeeting Bay northward to Richmond. (See also Section VIII.)
	9	Topography	A. W. Longfellow, assistant	Detailed plane-table survey of the shores of Middle Bay, Harpswell Cove, Sebaskahegan Island, and Quohog Bay, Me.
	10	Hydrography	Horace Anderson, sub-assistant...	Hydrography of Ewin's Narrows, Long Reach, and Doughty's Cove, near Harpswell, Me., and of Middle Bay and Maquoit Bay. (See also Section IX.)
	11	Triangulation, topography, and hydrography.	J. A. Sullivan, Charles Hosmer, and J. W. Donn, assistants; H. Anderson, sub-assistant; J. N. McClintock, aid.	Special survey of the harbor and city of Portland, Me., for the city authorities. (See also Sections III, V, and IX.)
	12	Topography	Hull Adams, assistant; Eugene Ellicott, aid.	Topography of the coast of Maine from Kennebunkport southward to Wells. (See also Section V.)
	13	Astronomical and telegraphic observations.	Professor Joseph Winlock, director, Cambridge Observatory; A. T. Mosman, assistant; F. Blake, jr., sub-assistant.	Observations at Cambridge, Mass., for determining the longitude of Omaha, in Nebraska, of Salt Lake City, in Utah Territory, and of San Francisco, in Cal. Azimuth determined at Cambridge, and the primary triangulation of the Atlantic coast brought into connection with the observatory. (See also Sections II, IV, and VII.)
	14	Astronomical and telegraphic observations.	Geo. W. Dean, assistant; F. Blake, jr., sub-assistant; Edward Goodfellow, assistant; J. Laurence Wilde, aid.	Preliminaries for the exchange of time-signals by means of the French submarine telegraphic cable, to determine the difference of longitude between Brest, in France, and Duxbury, Mass. (See also Sections II, IV, VII, VIII, IX, and X.)

APPENDIX No. 1—Continued.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION I—Continued.	No. 15	Triangulation	S. C. McCorkle, assistant	Triangulation to determine points for the plane-table survey of the shores of Narraganset Bay, R. I. (See also Section VII.)
	16	Topography	A. M. Harrison, assistant; H. G. Ogden, sub-assistant.	Detailed plane-table survey continued at the head of Narraganset Bay, between Warren and Fall River; also on the western shore from Wickford south to Bissel's Cove, and topographical survey of Canonicut Island. (See also Sections II and V.)
		Tidal and meteorological observations.	A. C. Mitchell; H. Howland	Series of observations commenced with a self-registering tide-gauge at North Haven, on the Fox Islands, in Penobscot Bay, Me. Observations continued at the Charlestown navy-yard, Mass.
		Drawing	Wm. B. McMurtrie, draughtsman.	Views for the harbor charts of Boston, Salem, Monomoy Point, Hyannis, Edgartown, Holmes' Hole, Woods' Hole, Tarpaulin Cove, Martha's Vineyard Sound, Buzzard's Bay, New Bedford, Mattapoisett, Sippican, Wareham, Newport, Narraganset Bay Entrance, and Point Judith.
SECTION II. Atlantic coast and sea-ports of Connecticut, New York, New Jersey, Pennsylvania, and Delaware, including bays and rivers.	1	Triangulation, topography, and hydrography.	H. L. Whiting, Charles Hosmer, and Charles Junken, assistants; H. G. Ogden, sub-assistant.	Special survey, for the Navy Department, of a site proposed for a naval station near New London, Connecticut, with longitudinal and cross sections. (See also Sections I and V.)
	2	Hydrography	F. F. Nes, assistant	Soundings and current observations, for the Engineer Department, in the channels near Sandy Hook and around the wreck of the steamer Scotland. Hydrography, for the Navy Department, of the Wallabout Channel and vicinity of the New York navy-yard. (See also Section IV.)
	3	Physical hydrography.	Henry Mitchell, assistant; H. L. Marindin, sub-assistant.	Special examination of the tides and currents in relation to the permanence of New York Harbor.
	4	Triangulation and astronomical observations.	A. T. Mosman, assistant; F. Blake, jr., sub-assistant.	Triangulation of the coast of New Jersey extended southward beyond Chapel Hill, and determination of azimuth at two stations. (See also Sections I, IV, and VII.)
	5	Reconnaissance	W. S. Edwards, assistant	Reconnaissance for the connection of Barnegat light-house with stations of the primary triangulation in New Jersey.
	6	Topography	Charles M. Bache, assistant; H. W. Bache, sub-assistant.	Topographical survey of Absecom Inlet, with adjacent parts of the coast of New Jersey, including Atlantic City.
	7	Reconnaissance	John Farley, assistant	Examination with reference to the condition and security of primary stations of the triangulation near the coast of New Jersey and Delaware.
		Tidal observations.	R. T. Bassett	Observations continued with the self-registering tide-gauge at Governor's Island in New York Harbor, and with the box-gauge at Brooklyn, N. Y.
SECTION III. Atlantic coast and bays of Maryland and Virginia, including sea-ports and rivers.	1	Geodetic operations.	C. O. Boutelle, assistant; James Thacher Boutelle, temporary aid.	Azimuth determined of lines in the primary triangulation at Seaton Station, Washington, D. C. Geodetic operations continued at Stabler in Maryland, and at Peach Grove in Virginia. (See also Section V.)
	2	Magnetic observations.	Charles A. Schott, assistant	Observations monthly at the magnetic station on Capitol Hill, Washington City, and determination of the secular change in the magnetic declination, dip, and horizontal intensity. (See also Section VIII.)
	3	Base line	Richard D. Cutts and R. E. Halter, assistants; C. Ferguson and F. W. Perkins, sub-assistants.	Measurement of a base line near Craney Island, Va., and its connection with adjacent stations of the triangulation of Chesapeake Bay. (See also Sections IV and V.)

APPENDIX No. 1—Continued.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION III—Continued.	No. 4	Topography and hydrography.	J. W. Donn, assistant; C. P. Dillaway, aid, (part of season.)	Shore-line survey and hydrography of Milford Haven, Piankatank River and other estuaries of Chesapeake Bay between the Rappahannock and the Potomac; also of the lower branches of those rivers, and soundings in the branches of the Patapsco River. (See also Section I.)
	5	Topography and hydrography.	W. W. Harding, sub-assistant; A. F. Pearl, aid.	Shore-line survey and hydrography of Pocomoke River, and of the Chesapeake estuaries between it and Cape Charles, Va. Soundings completed in the vicinity of Smith's Island, Tangier Island, Fox Island, and in Little Annemessex River, Md.
	6	Triangulation and reconnaissance.	F. H. Gerdes, assistant; C. P. Dillaway, aid, (part of season.)	Special examination and verification of the chart-positions of lights and buoys on the shores of Chesapeake Bay and its branches, from Havre-de-Grace to Norfolk.
		Tidal observations.	E. F. Krebs	Continuous observations with the self-registering tide-gauge at Old Point Comfort, Va.
SECTION IV.				
Atlantic coast, and sounds of North Carolina, including sea-ports and rivers.	1	Base-line and triangulation.	Richard D. Cutts, assistant; C. Ferguson and F. W. Perkins, sub-assistants.	Measurement of base on the coast of Virginia, below Cape Henry, and triangulation southward from it toward the Bodies Island base, N. C. (See also Section III.)
	2	Astronomical observations.	A. T. Mosman, assistant; F. W. Perkins, sub-assistant.	Azimuth determination at a station on Knott's Island, in the northern part of Currituck Sound, Va. (See also Sections I, II, and III.)
	3	Hydrography	Robert Platt, Acting Master U. S. N., assistant; Gershom Bradford, sub-assistant; J. B. Adamson, aid.	Hydrography of the coast of North Carolina, in the vicinity of the Wimble Shoals. (See also Section VI.)
	4	Triangulation	G. A. Fairfield, assistant; F. W. Perkins, sub-assistant, (part of season;) J. Hergesheimer, aid, (part of season.)	Triangulation continued in Pamlico Sound, N. C., between Neuse River Entrance and Ocracoke Inlet. (See also Section III.)
	5	Topography	F. W. Dorr, assistant; H. W. Bache, sub-assistant; Jos. Hergesheimer, aid.	Topography of the western side of Pamplico Sound, N. C., from Pamplico River Entrance to Swan Creek, including Mouse Harbor, Jones' Bay, and Bay River, with adjacent branches of the sound, and the islands in the vicinity. (See also Section I.)
	6	Hydrography	F. F. Nes, assistant; L. B. Wright and G C. Schaeffer, jr., aids.	Hydrography of the southwestern part of Pamplico Sound, N. C., including Bay River, Jones' Bay, Mouse Harbor, and the approaches to Neuse River and Pamplico River. (See also Sections I and II.)
	7	Astronomical observations.	Richard D. Cutts and A. T. Mosman, assistants; F. W. Perkins, sub-assistant.	Solar eclipse of August 7, observed at Bristol in Tennessee; and determination of the latitude and longitude of the station. (See also Sections I and III.)
SECTION V.				
Atlantic coast and sea-water channels of South Carolina and Georgia, including sounds, harbors, and rivers.	1	Hydrographic reconnaissance.	R. E. Halter, assistant; G. W. Bissell and W. I. Vinal, aids.	Special hydrographic examination, for the Light-House Board, of the entrance to Charleston Harbor, S. C., for the sites of range-beacons to aid in navigating the bar and channels. (See also Section III.)
	2	Triangulation	C. O. Boutelle, assistant	Stations selected for connecting the primary triangulation of the coast of South Carolina with the astronomical station at Savannah. (See also Section III.)
	3	Topography	Charles Hosmer, assistant; H. G. Ogden, sub-assistant.	Plane-table survey, including the water-courses of the Romerly marshes, Ga.; and topography along the west side of the Inland Passage, from Ogeechee River southward to the head-waters of Sapelo Sound, Ga. (See also Sections I and II.)

APPENDIX No. 1—Continued.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION V—Continued.	No. 4	Topography	W. H. Dennis, assistant; O. H. Tittmann, aid.	Topography of Altamaha Sound, Ga., including Darien River and Mud River on the north, and Buttermilk Sound, Macky's River, Back River, and part of Hampton River on the south side; also Wolf Island and others between it and St. Simon's Island. (See also Section I.)
	5	Topography	C. T. Iardella, assistant; Eugene Ellicott, aid.	Topographical survey of St. Simon's Island and of Long Island, on the coast of Georgia. (See also Section I.)
	6	Hydrography	R. E. Halter, assistant; G. W. Bissell and W. I. Vinal, aids.	Hydrography of the approaches and bar of St. Andrew's Sound, Ga., including also part of Jekyl Sound.
	7	Hydrography	R. E. Halter, assistant; G. W. Bissell and W. I. Vinal, aids.	Soundings on the bar of St. Mary's River, in the vicinity of Fernandina, Fla., and selection of sites for beacon-range lights on Amelia Island. (See also Section III.)
SECTION VI.				
Atlantic and Gulf coast of the Florida Peninsula, including the reefs and keys, and the seaports and rivers.	1	Hydrography	Acting Master Robert Platt, U. S. N., assistant; Gershom Bradford, sub-assistant; J. B. Adamson, aid.	Lines of soundings from Florida Reef across the trough of the Gulf Stream. Current observations and hydrography of the vicinity of the Marquesas and Tortugas Groups. (See also Section IV.)
		Researches	L. F. Pourtales, assistant	Researches in the deep-sea bottom outside of the Florida Reef and in the Gulf Stream. (See also Section VIII.)
SECTION VII.				
Gulf coast and sounds of Western Florida, including the ports and rivers.	1	Triangulation and topography.	S. C. McCorkle, assistant; H. M. De Wees, sub-assistant.	Triangulation and topography of St. Andrew's Bay, on the western coast of Florida. (See also Section I.)
	2	Astronomical observations.	J. G. Oltmanns, assistant	Geodetic connection of the Pensacola Bay and Mobile Bay triangulations, completed by linear measurement and the determination of azimuth at stations on the Gulf coast.
	3	Astronomical observations.	Professor Joseph Winlock, director Cambridge Observatory; Geo. W. Dean, assistant; C. S. Peirce, F. H. Agnew, and F. Blake, jr., sub-assistants.	Solar eclipse of August 7, observed at Shelbyville and at Bardstown, in Kentucky. (See also Sections I, II, IV, and X.)
SECTION VIII.				
Gulf coast and bays of Alabama, and the sounds of Mississippi and Louisiana to Vermilion Bay, including the ports and rivers.	1	Astronomical observations.	Benjamin Peirce, superintendent; Chas. A. Schott and L. F. Pourtales, assistants; Jas. M. Peirce, E. P. Seaver, J. B. Warner, R. A. McLeod, W. P. Montague, and C. N. Fay, aids.	Solar eclipse of August 7, observed at Springfield and at Bloomington, in Illinois. (See also Sections III and VI.)
	2	Astronomical observations.	Edward Goodfellow, assistant; E. P. Austin, aid.	Longitude and latitude determined at Springfield and Mattoon, in Illinois; at Des Moines and Burlington, in Iowa, and the longitude of Bushnell and Julesburg, in Nebraska. (See also Sections I and IX.)
	3	Astronomical observations.	J. E. Hilgard and Edward Goodfellow, assistants.	Solar eclipse of August 7, observed at Des Moines and Cedar Falls, in Iowa. (See also Sections I and IX.)
	4	Astronomical observations.	J. E. Hilgard, assistant; F. Blake, jr., sub-assistant.	Determination of latitude and longitude at Cedar Falls, in Iowa. (See also Sections I, II, IV, and VII.)
	5	Triangulation and topography.	C. H. Boyd, assistant; H. L. Marindin, sub-assistant.	Triangulation and topography of the western side of Isle au Breton Sound, Louisiana, from Battledore to Point Chico; and of the eastern side from Isle au Breton to the Chandeleurs. (See also Section I.)
	6	Hydrography	F. P. Webber, assistant; F. D. Granger, sub-assistant; R. B. Palfrey, aid.	Hydrography of Isle au Breton Sound, Louisiana, from Passe à Loutre eastward to Grand Gosier, and northward beyond Isle au Breton. (See also Section I.)

APPENDIX No. 1—Continued.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION IX.				
Gulf coast of Western Louisiana and of Texas.	No. 1	Astronomical and telegraphic observations.	Edward Goodfellow, assistant; E. P. Austin, aid.	Longitude determined at Omaha by the telegraphic method. Observations for latitude and the magnetic elements. Meridian line traced and marked. (See also Sections I and VIII.)
	2	Hydrography	Horace Anderson, sub-assistant; J. N. McClintock, aid.	Soundings completed in the southern part of Aransas Bay, Texas; also in the shore approaches of Corpus Christi Bay, and through the channel leading from it to the Gulf of Mexico by Corpus Christi Pass. (See also Section I.)
SECTION X.				
Pacific coast of California, including the bays, harbors, and rivers.	1	Astronomical observations.	George Davidson, assistant; S. R. Throckmorton, jr., aid.	Latitude and azimuth determined at Station Santa Barbara. (See also Sections XI and XII.)
	2	Topography	W. E. Greenwell, assistant; Stehman Forney, aid.	Plane-table survey of the coast of California from Santa Barbara eastward toward San Buenaventura.
	3	Hydrography	Edward Cordell, assistant; G. Farquhar, sub-assistant.	Inshore soundings of the Santa Barbara channel extended southward and eastward from Santa Barbara, and offshore soundings crossing the channel to Santa Cruz Island. Hydrography of Coxo Harbor. Development of Harlech Castle rock near Piedras Blancas, and soundings southward and westward of the South Farallon.
	4	Topography	Cleveland Rockwell, assistant; L. A. Sengteller, sub-assistant.	Plane-table survey of the coast in the vicinity of Point Conception, California. (See also Section XI.)
	5	Topography	A. F. Rodgers	Completion of the detailed map of surveys previously made on the peninsula near San Francisco, showing the land approaches.
	6	Astronomical and telegraphic observations.	George Davidson, assistant; S. R. Throckmorton, aid.	Longitude of San Francisco, Cal., determined by time-signals exchanged with observers at Salt Lake City, in Utah; at Omaha, in Nebraska; and at Cambridge, Massachusetts. Special examination of the vicinity of Point Reyes for light-house purposes. (See also Sections XI and XII.)
	7	Astronomical and telegraphic observations.	G. W. Dean, assistant; F. H. Agnew, sub-assistant.	Longitude, latitude, and the magnetic elements determined; and meridian line traced and marked at Salt Lake City, in Utah Territory. Time-signals exchanged for determining the longitude of Brigham City. (See also Sections I and VII.)
	8	Hydrography	Edward Cordell, assistant; G. Farquhar, sub-assistant.	Hydrographic development of an extensive shoal to the westward of Point Reyes, Cal. (See also Section XI.)
	9	Astronomical observations and triangulation.	George Davidson, assistant; S. R. Throckmorton, aid.	Latitude, longitude, and vertical elevation determined at Cape Mendocino light-house, Cal., and connection of that point with the coast triangulation. The position of Blunt's Reef determined, and of Redding's Rock, and the great buoy off the entrance to Humboldt Bay. (See also Sections XI and XII.)
	10	Reconnaissance, triangulation, topography, and hydrography.	A. F. Rodgers, assistant; A. P. Redding, aid.	Survey of the coast from Humboldt Bay to Cape Mendocino, and hydrography of the lower part of Eel River, Cal.
		Tidal and meteorological observations.	Major G. H. Elliot, U. S. Engineer; A. Cassidy; H. E. Uhrlandt, (part of season;) Wm. Knapp, (part of season.)	Series of observations with self-registering tide-gauges continued at San Diego and at Fort Point near San Francisco. (See also Section XI.)
SECTION XI.				
Pacific coast of Oregon and of Washington Territory, including the interior bays, ports, and rivers.	1	Topography	A. W. Chase, sub-assistant; M. Liprowitz, aid.	Plane-table survey of the vicinity of Point St. George, near Crescent City, Cal., and determination in position of the Dragon Rocks. Triangulation and topography of the vicinity of Cape Orford, on the coast of Oregon.

APPENDIX No. 1—Continued.

Coast sections.	Parties.	Operations.	Persons conducting operations.	Locations of work.
SECTION XI—Continued.	No. 2	Astronomical observations.	George Davidson, assistant; S. R. Throckmorton, aid.	Longitude determined at Astor Point, Oregon. Views drawn of important capes and rocks along the coast of Oregon and of Washington Territory. Latitude and longitude determined at Esquimalt and Victoria, on Vancouver Island. (See also Sections X and XII.)
	3	Topography	Cleveland Rockwell, assistant; L. A. Songteller, sub-assistant.	Plane-table survey of the north side of the entrance to Columbia River, Oreg., and of the coast adjacent. (See also Section X.)
	4	Hydrography	Edward Cordell, assistant; G. Farquhar, sub-assistant.	Completion of hydrographic charts of the lower part of the Columbia River. (See also Section X.)
	5	Triangulation and topography.	James S. Lawson, assistant; J. J. Gilbert, aid.	Triangulation and topography of Port Discovery, W. T. Astronomical station at Esquimalt Harbor connected with the primary triangulation of the Strait of Fuca.
		Tidal and meteorological observations.	Major G. H. Elliot, U. S. Engineer; L. Wilson.	Observations continued at Astoria, Oreg., with the self-registering tide-gauge. (See also Section X.)
SECTION XII.				
Pacific coast, Alaska Territory.	1	Astronomical observations.	George Davidson, assistant; S. R. Throckmorton, aid.	Solar eclipse of August 7, observed at a station on the Chilkaht River, in Alaska Territory. Geographical positions determined at Fort Wrangel on the Stakeen River, and at points in Chatham Strait. Reconnaissance in the Alexander Archipelago. Tidal observations at Unalaska. (See also Sections X and XI.)

APPENDIX No. 2.

Information furnished from the Coast Survey Office, by tracings from original sheets, &c., in reply to special calls, during the year ending November, 1869.

Date.		Names.	Data furnished.
1868.			
December	11	Daniel T. Van Buren, esq	Shore-line survey of the Hudson River, from Port Ewen to Tyler's Point.
	15	Baltimore and Potomac Railroad Company	Hydrographic and topographical surveys of Eastern Branch of Potomac River, from above Benning's bridge to Anacostia bridge.
	30	S. B. Driggs, esq	All tide-marsh of Staten and Long Islands.
	31	William S. Dexter, esq., agent of the Franco-American Telegraph Cable Company.	Hydrographic and topographical survey from Plymouth to Duxbury beach.
1869.			
January	13	Light-house Board	Proof of lower bay, New York, with soundings and curves.
February	9	..........do	Reconnaissance of Sitka Harbor, Alaska Ter.
	9	Engineer Bureau, United States Army	Topographical survey of western shore of Mobile Bay, from city of Mobile to Deer River.
	27	Northern Pacific Railroad Company	Compiled map of Puget Sound, W. T.
	23	H. C. Yarrow, acting assistant surgeon United States Army.	Topographical survey of Bedloe's Island, New York Harbor.
April	13	City of Mobile, Alabama	Hydrographic survey of city front, with part of bay.
	27	Light-house Board	Topographical survey of Point Año Nuevo and Point Reyes, Cal.
	27	Daniel T. Van Buren, esq	Hydrographic survey of Rondout Creek, from South Rondout to Hamilton Island.
May	20	Brevet Major General A. A. Humphreys, Chief of Engineers.	Sketches of Sandy Hook, showing progressive changes from 1778 to 1862.
	25	Brevet Major General A. A. Humphreys, Chief of Engineers.	Hydrographic survey of San Diego Bay, Cal.
June	8	Light-house Board	Topographical survey near Charleston light-house.
	16	H. S. Benson, esq	Topographical survey of the shores of Isle of Wight Bay, Md.
	28	Rear-Admiral S. W. Godon, United States Navy	Hydrographic survey of Wallabout Channel, New York Harbor.
July	10	Major General J. G. Foster, United States Army	Projection, scale 1-10,000, vicinity of West Point, N. Y.
	17	........do	Shore-line of the Hudson River, vicinity of West Point, N. Y.
	24	Norman W. Wheeler, esq	Hydrographic survey of the Raritan River, from South Amboy to New Brunswick, N. J.
August	3	Samuel McElroy, esq., superintendent King's County Survey, N. Y.	Topographical survey from Brooklyn south to Coney Island, and east to Spring Creek, Jamaica Bay, Long Island.
	7	Willis Gaylord, esq	Hydrographic survey of Broad River, from its mouth to and including Whale Branch, S. C.
	11	William J. Bowditch, esq	Hydrographic and topographical surveys of Breed Island, Boston Harbor.
	11	Navy Department	Hydrographic and topographical surveys of site for navy-yard near New London, Conn.
	17	........do	Hydrographic survey of the Mystic River, vicinity of the Boston navy-yard.
	23	George S. Green, esq	High and low water lines of Narraganset Bay, from Pawtuxet to Potowomuth River.
	31	Carolan O. B. Bryant, esq	Topographical survey of the east side of San Francisco Peninsula, from Islay's Creek to Point San Bruno, Cal.
	31	Rear-Admiral S. P. Lee, United States Navy	Enlarged copy of Seavy's Island, Portsmouth Harbor, N. H.
September	13	Willis Gaylord, esq	Hydrographic survey of the Beaufort River, and south side of St. Helena Island, S. C.
	24	Howard Potter, esq	Topographical survey of the coast of New Jersey, from above Long Branch to Deal.
	28	P. Bonnett, esq	Hydrographic and topographical surveys of Staten Island Sound, from Shooter's Island to Dividing Creek.
October	1	F. W. Elbrey, assistant surgeon United States Army	Topographical survey of Governor's Island, New York Harbor.
	6	R. W. Templeman & Company	Topographical survey of Lynn Haven Inlet, with shores of Lynn Haven River and Broad Bay, Va.
	21	East River Association, New York	Hydrographic survey of the East River, from Bushwick Creek to Ward's Island.
November	15	T. M. R. Talcott, esq	Topographical and hydrographic surveys of the Piankatank River, Va.
	15	Engineer Bureau, United States Army	Hydrographic survey of Narraganset Bay, R. I.
	23	Light-house Board	Hydrographic survey of the Delaware River, vicinity of Fort Mifflin.

APPENDIX No. 3.

DRAWING DIVISION.

Charts completed or in progress during the year ending November, 1869.

1. Hydrography. 2. Topography. 3. Drawing for photographic reduction. 4. Details on photographic outlines. 5. Verification. 6. Lettering.

Titles of charts.	Scale.	Draughtsman.	Remarks.
Winter Harbor, Me	1–20, 000	2. H. Lindenkohl	Completed.
Coast chart No. 4. Naskeag Head to White Head light	1–80, 000	3. L. Karcher. 4. H. Lindenkohl	
Sketch for connecting the primary triangulation of the coast with the northeast boundary survey.	1–600, 000	2. A. Lindenkohl. 2. F. Fairfax	Completed.
Coast chart No. 5. White Head light to Seguin Island light	1–80, 000	1. A. Lindenkohl. 3. L. Karcher. 4. H. Lindenkohl.	
Casco Bay, Me	1–40, 000	1. A. Lindenkohl	Completed.
Coast chart No. 8. Boon Island light to Gloucester Harbor	1–80, 000	1. A. Lindenkohl	Completed.
Coast chart No. 9. Boston Bay and approaches	1–80, 000	1. L. Karcher. 1. A. Lindenkohl	Additions.
Coast chart No. 10. Cape Cod Bay, Mass	1–80, 000	3. L. Karcher	Completed.
Coast chart No. 11. Monomoy and Nantucket Shoals, Mass	1–80, 000	3. L. Karcher. 4. H. Lindenkohl	Additions.
General coast chart No. II. Cape Ann to Gay Head	1–400, 000	2. A. Lindenkohl	Additions.
Coast chart No. 13. Narraganset Bay, R. I	1–80, 000	3. L. Karcher. 4. H. Lindenkohl	
Greenwich Bay, R. I	1–20, 000	1. L. Karcher	
Narraganset Bay, (lower sheet)	1–40, 000	1. A. Lindenkohl	
Narraganset Bay, (upper sheet)	1–40, 000	1. A. Lindenkohl	
Coast chart No. 20, New York Bay and Harbor	1–80, 000	1. L. Karcher	Additions.
Vicinity of New London, Connecticut, (site for navy-yard)	1–1, 200	1, 2. L. Karcher	Completed.
New York, (lower bay)	1–40, 000	1. L. Karcher. 2. A. Lindenkohl	Completed.
New York, (upper bay)	1–40, 000	2. H. Lindenkohl	
General coast chart No. IV. Cape May to Cape Henry	1–400, 000	1. H. Lindenkohl. 1. A. Lindenkohl	Additions.
Potomac River, No. 1. Entrance to Piney Point	1–60, 000	1, 2. H. Lindenkohl	Additions.
Potomac River, No. 2. Piney Point to Lower Cedar Point	1–60, 000	1, 2. H. Lindenkohl	Additions.
General coast chart No. V. Cape Henry to Cape Lookout	1–400, 000	1. H. Lindenkohl. 1. A. Lindenkohl	Additions.
Port of New Berne, N. C	1–40, 000	1. L. Karcher. 2. F. Fairfax	Completed.
Coast chart No. 54. Long Island to St. Helena Sound, including Charleston Harbor.	1–80, 000	1. A. Lindenkohl. 1. H. Lindenkohl	Completed.
Coast chart No. 55. Hunting Island to Ossabaw Sound, including Savannah River.	1–80, 000	1. A. Lindenkohl. 2. H. Lindenkohl	
Charleston Harbor, S. C	1–30, 000	1. A. Lindenkohl	Completed.
St. Catherine's Sound, Ga	1–40, 000	1. L. Karcher	
Coast chart No. 56. Savannah to Doboy Sound	1–80, 000	2. H. Lindenkohl	
General coast chart No. X. Straits of Florida	1–400, 000	1, 2. H. Lindenkohl	Additions.
Coast chart No. 58. St. Mary's and St. John's Rivers, and adjacent coast, Fla.	1–80, 000	2. H. Lindenkohl	
Coast chart No. 69. Newfound Harbor Key to Boca Grande Key, Fla.	1–80, 000	2. F. Fairfax	Additions.
Coast chart No. 75. Charlotte and St. Carlos Harbors, Fla	1–80, 000	2. H. Lindenkohl	
Coast chart No. 94. Mississippi Delta	1–80, 000	1. A. Lindenkohl	
General coast chart No. XVI. Galveston to Rio Grande	1–400, 000	2. H. Lindenkohl. 1. A. Lindenkohl	Additions.
Coast chart No. 104. Galveston Bay	1–80, 000	2. A. Lindenkohl	Additions.
Galveston entrance, Tex	1–40, 000	2. F. Fairfax	Completed.
Coast chart No. 105. Galveston, (east bay)	1–80, 000	1. A. Lindenkohl	Additions.
Entrance to San Francisco Bay, Cal	1–50, 000	2. H. Lindenkohl	Additions.
Suisun Bay, Cal	1–40, 000	2. H. Lindenkohl	
Western coast, from San Diego to San Francisco	1–1, 200, 000	1. A. Lindenkohl. 2. A. Lindenkohl	Additions.
Western coast, (middle sheet,) San Francisco to Umpquah River.	1–1, 200, 000	1. A. Lindenkohl. 2. A. Lindenkohl	Additions.
Yaquina Bay, Oreg	1–20, 000	1. A. Lindenkohl	
Puget Sound, W. T	1–200, 000	1, 2. A. Lindenkohl	Completed.
Port Madison, W. T	1–20, 000	1. F. Fairfax. 2. F. Fairfax	Completed.
Western coast, (northern sheet,) Umpquah River to northwest boundary.	1–1, 200, 000	1, 2. A. Lindenkohl	Additions.
Northwest chart No. 1. Cape Flattery to Dixon Entrance	1–1, 200, 000	1, 2. A. Lindenkohl	
Alaska and adjoining territory	1–2, 400, 000	1, 2, 6. H. Lindenkohl	Completed.
SKETCHES DRAWN FOR PHOTO-LITHOGRAPHING.			
Port Conclusion, Alaska Territory		1, 2, 6. H. Lindenkohl	
Port Stewart, Alaska Territory		1, 2, 6. H. Lindenkohl	

APPENDIX No. 3—Continued.

Titles of charts.	Scale.	Draughtsman.	Remarks.
Bucarelli Bay, Alaska Territory		1, 2, 6. H. Lindenkohl	
Port Bazan, Alaska Territory		1, 2, 6. H. Lindenkohl	
Tomgas Harbor, Alaska Territory		1, 2, 6. H. Lindenkohl	
Kaigan Harbor, Alaska Territory		1, 2, 6. H. Lindenkohl	
Sitka Harbor, Alaska Territory		1, 2, 6. H. Lindenkohl	
Entrance to Cross Sound, Alaska Territory		1, 2, 6. H. Lindenkohl	
Olga Gulf, Alaska Territory		1, 2, 6. H. Lindenkohl	
Whale Bay, Alaska Territory		1, 2, 6. H. Lindenkohl	
Cross Harbor, Alaska Territory		1, 2, 6. H. Lindenkohl	
Port Spaskia, Alaska Territory		1, 2, 6. H. Lindenkohl	
Port Protection, Alaska Territory		1, 2, 6. H. Lindenkohl	
Anchorage of Point Highfield, Alaska Territory		1, 2, 6. H. Lindenkohl	
Kukak Bay, Alaska Territory		1, 2, 6. H. Lindenkohl	
Port Chatham, Alaska Territory		1, 2, 6. H. Lindenkohl	
Entrance to Kaknu River, Alaska Territory		1, 2, 6. H. Lindenkohl	
Port Chalmers, Alaska Territory		1, 2, 6. H. Lindenkohl	
Port Etches, Alaska Territory		1, 2, 6. H. Lindenkohl	
Port Mulgrave, Alaska Territory		1, 2, 6. H. Lindenkohl	
Altuya Bay, Alaska Territory		1, 2, 6. H. Lindenkohl	
St. Paul Harbor, Alaska Territory		1, 2, 6. H. Lindenkohl	
Cherinoffsky Bay, Alaska Territory		1, 2, 6. H. Lindenkohl	
Kilulук Bay, Alaska Territory		1, 2, 6. H. Lindenkohl	
Coal Harbor, Alaska Territory		1, 2, 6. H. Lindenkohl	
Delarof Harbor, Alaska Territory		1, 2, 6. H. Lindenkohl	
Port Graham, Alaska Territory		1, 2, 6. H. Lindenkohl	
Port Wrangel, Alaska Territory		1, 2, 6. H. Lindenkohl	
Illiouliouk and Captain's Harbors, Alaska Territory		1, 2, 6. H. Lindenkohl	
Constantine Harbor, Alaska Territory		1, 2, 6. H. Lindenkohl	
Bay of Waterfalls, Alaska Territory		1, 2, 6. H. Lindenkohl	
Chichagoff Harbor, Alaska Territory		1, 2, 6. H. Lindenkohl	
Kiriloff Bay, Alaska Territory		1, 2, 6. H. Lindenkohl	
Suchikova Bay, Alaska Territory		1, 2, 6. H. Lindenkohl	
Korovinsky Bay, Alaska Territory		1, 2, 6. H. Lindenkohl	
Nazan Bay, Alaska Territory		1, 2, 6. H. Lindenkohl	
Plover Bay, Eastern Siberia		1, 2, 6. H. Lindenkohl	

APPENDIX No. 4.

ENGRAVING DIVISION.

Plates completed, continued, or commenced during the year 1869.

1. Outlines. 2. Topography. 3. Sanding. 4. Lettering.

Title of plates.	Scale.	Engravers.
COMPLETED.		
Kennebec and Sheepscot Rivers	40, 000	3. W. A. Thompson. 4. E. A. Maedel.
Caloosa Entrance	40, 000	2. J. C. Kondrup. 4. J. G. Thompson.
Galveston Entrance	40, 000	1 and 2. R. F. Bartle. 3. W. A. Thompson. 4. J. G. Thompson.
Half-Moon Bay	20, 000	2. W. A. Thompson. 4. J. G. Thompson.
Point Sal Roadstead	20, 000	2. W. A. Thompson. 3. F. W. Benner. 4. J. G. Thompson.
Cordell Bank	200, 000	1. R. F. Bartle. 4. E. H. Sipe.
Washington Sound	200, 000	4. A. Petersen and J. G. Thompson.
Shilshole Bay	20, 000	4. J. G. Thompson.
Sorensen's Pantograph	....	J. C. Kondrup.
CONTINUED.		
Northwest Coast of America No. 1	1, 200, 000	4. A. Petersen and J. G. Thompson. 1. R. F. Bartle.
General coast charts:		
No. I.—Quoddy Head to Cape Cod	400, 000	1 and 2. J. Enthoffer.
No. II.—Cape Ann to Gay Head	400, 000	1 and 2. A. M. Maedel.
No. IV.—Cape May to Cape Henry	400, 000	1 and 2. A. M. Maedel. 3. H. S. Barnard and F. W. Benner. 4. E. A. Maedel.
No. V.—Cape Henry to Cape Lookout	400, 000	1 and 2. A. M. Maedel. 3. F. W. Benner. 4. E. A. Maedel.
No. VII.—Cape Roman to St. Mary's River	400, 000	1. A. M. Maedel.
No. X.—Straits of Florida	400, 000	2. A. Sengteller. 3. H. S. Barnard and F. W. Benner. 4. E. A. Maedel.
No. XVI.—Galveston to Rio Grande	400, 000	1 and 2. A. M. Maedel. 3. W. A. Thompson. 4. J. Knight and E. A. Maedel.
Coast charts:		
No. 5.—Whitehead Light to Seguin Light	80, 000	1 and 2. J. Enthoffer. 4. J. Knight.
No. 8.—Wells Beach to Cape Ann	80, 000	1 and 2. A. Sengteller. 3. H. S. Barnard. 4. J. Knight and E. A. Maedel.
No. 9.—Boston Bay	80, 000	3. H. S. Barnard. 4. E. A. Maedel and J. Knight.
No. 10.—Cape Cod Bay	80, 000	1 and 2. J. Enthoffer and H. C. Evans. 4. E. A. Maedel.
No. 13.—Narraganset Bay	80, 000	1 and 2. J. Enthoffer and H. C. Evans. 4. J. Knight.
No. 28.—Isle of Wight to Chincoteague	80, 000	1 and 2. R. F. Bartle. 4. J. Enthoffer.
No. 30.—Chesapeake Entrance	80, 000	4. J. Knight.
No. 54.—Long Island to Hunting Island	80, 000	3. H. S. Barnard. 4. E. A. Maedel.
No. 55.—Hunting Island to Ossabaw Island	80, 000	1 and 2. A. Sengteller. 4. E. A. Maedel.
No. 56.—Savannah to Doboy Strait	80, 000	1. A. Sengteller.
No. 79.—Cedar Keys, &c	80, 000	1 and 2. A. Sengteller.
No. 94.—Mississippi River Entrance	80, 000	1. A. Rolle. 2. A. M. Maedel. 3. H. S. Barnard. 4. E. A. Maedel.
Damariscotta and Medomack Rivers	40, 000	1 and 2. E. Molkow and A. M. Maedel.
Bath to Booth Bay	40, 000	2. T. W. B[illegible]ner. 4. A. Petersen.
Casco Bay	40, 000	3. H. S. Barnard and W. A. Thompson. 4. A. Petersen.
Boston Harbor	40, 000	3. H. S. Barnard. 4. J. Knight and A. Petersen.
Narraganset Bay, (upper)	40, 000	1. E. Molkow and T. C. Kondrup. 4. J. Knight.
New York Bay and Harbor, (upper)	40, 000	1. E. Molkow and R. F. Bartle. 2. H. C. Evans. 3. E. A. Maedel.
New York Bay and Harbor, (lower)	40, 000	2. H. C. Evans. 4. E. A. Maedel.
St. Helena Sound	40, 000	2. J. C. Kondrup. 3. W. A. Thompson. 4. J. G. Thompson.
Suisun Bay	40, 000	4. F. W. Benner.
Tillamook Bay	20, 000	2. A. M. Maedel. 3. F. W. Benner. 4. J. G. Thompson.
COMMENCED.		
Coast charts:		
No. 4.—Penobscot Bay	80, 000	1 and 2. J. Enthoffer.
No. 75.—Charlotte Harbor, &c	80, 000	1. A. Rolle and J. C. Kondrup. 2. J. C. Kondrup. 4. E. A. Maedel.
New York Entrance	40, 000	1 and 2. A. Sengteller and W. A. Thompson. 3. W. A. Thompson. 4. E. A. Maedel.
Greenwich Bay	20, 000	1. J. C. Kondrup. 4. J. G. Thompson and E. H. Sipe.
Port of Newbern	40, 000	1. J. G. Thompson. 3. R. F. Bartle. 4. J. G. Thompson.
St. Catherine's Sound	40, 000	1. W. A. Thompson. 3. F. W. Benner. 4. J. G. Thompson and E. H. Sipe.
Galveston Entrance	40, 000	1 and 2. R. F. Bartle. 3. W. A. Thompson. 4. J. G. Thompson.
Cordell Bank	200, 000	1. R. F. Bartle. 4. E. H. Sipe.
Land approaches to San Francisco	40, 000	1. E. Molkow, pantographing.
Yaquina Entrance	20, 000	1. R. F. Bartle. 4. E. H. Sipe.
Puget Sound	200, 000	1. J. G. Thompson. 2. A. M. Maedel. 3. H. S. Barnard. 4. A. Petersen and J. G. Thompson.
Sorensen's Pantograph	....	J. C. Kondrup.
Rules for lettering 1-80,000 charts, U. S. Coast Survey.	....	4. J. Knight.

APPENDIX No. 5.

ON THE RECLAMATION OF TIDE-LANDS AND ITS RELATION TO NAVIGATION· BY HENRY MITCHELL, CHIEF IN PHYSICAL HYDROGRAPHY, UNITED STATES COAST SURVEY.

PART I.—GENERAL DISCUSSION OF THE SUBJECT.

Relations of the Coast Survey.—Although, as a general rule, marshes reclaimed from rivers and tide-waters by drainage are the most fertile and enduring of all soils, the cases are exceptional where enterprises in this direction are profitable prior to the period when an augmenting population has exhausted the resources of the uplands. In our own country, lands have been reclaimed from time to time since the earliest settlement; but until recently efforts of this kind have been confined to high marshes bordering upon rivers or sheltered bays, and in most cases for the growth of special crops. The period, however, has arrived when the sea-board of our Northern States has become so densely populated that projects of reclamation are becoming popular, and promise favorable investments for capital. The topographical sheets of our Coast Survey, which reach the public only as printed maps, upon scales so reduced that many of the details and most of the original spirit are lost, furnish us with an amount of information relative to the extent and character of the tide-marshes along our shores scarcely appreciated by those outside of our service. These surveys in the manuscript, as they reach us from the plane-table, furnish not only the measures of reclaimable marshes, but exhibit the configuration of the surrounding country so boldly, and at the same time so minutely, that one can scarcely cast his eyes over one of these sheets without superinducing upon it tempting schemes of conquest. To the engineer every detail of the topography has a practical value, which he cannot afford to overlook in developing a scheme of drainage.

In the reclamation of tide-lands it is all-important, because it is the best economy, to so arrange the dikes, canals, and sluices that the largest possible area shall be included in one comprehensive plan. These enterprises are profitable in the measure that they combine individual interests and assume the proportion of public works. In the same measure also the Coast Survey, I think, should be ready and willing to furnish information, not only through maps and printed reports, but also through its officers in person; the topographer with his sheet before him can be of more value in oral discussions of projects than by writing reports, because he cannot know in advance the means or the wants of the people. He is not at all competent to originate the project, but very well able to assist a community in doing so. In a corps like ours, composed of men selected carefully and trained to scrupulous truthfulness in the study of nature, I should feel no anxiety with regard to the character of the advice that individual officers might give. They feel their reputations involved in the success of the undertakings as well as in the preservation of their entire freedom from private interests.

The relations of encouragement and of assistance, which I have indicated as my notion of a proper policy for the Coast Survey, are not the only or the most important interests which we have in these opening enterprises; we should be watchful of them, because they involve effects upon navigable channels sometimes beneficial, sometimes detrimental. We should favor legislative grants in some cases and oppose them in others. Perhaps there is no navigable stream that can be safely left to the exclusive control of the communities upon its banks. In my studies of foreign works of reclamation, whose histories have been preserved through long periods, I scarcely find the instance where the enclosure of tide-lands in the vicinity of channels is neutral in its effects upon navigation. It seems to me, therefore, that our first thought upon this subject should be from a commercial point of view.

To any one whose memory goes back to the time when railways were unknown, or to any one whose travels have extended beyond the sound of the steam-whistle, I need hardly say that the recent improvements in land transportation have had a tendency to diminish with us the number of small vessels known as "market-men," whose mission it has been to ply between the great seaports and the little coves and inlets of the adjacent coast. In the early settlement of the country it was all-important to the agriculturist to find a location in the vicinity of a navigable water-

course, in order that the products of his labor might be within reach of a market; and on the other hand, very shallow streams and really dangerous harbors became, in some cases, the sites of considerable commerce, simply because they afforded the only available avenues to a productive country.

In these modern times a change has come over the spirit of migration and trade, and among its first fruits we find that many of the smaller streams and harbors are falling into comparative disuse. The time is come indeed when the farmer covets the rich soils that lie submerged, and is quite ready to entertain any project of reclamation regardless of its effect upon navigation.

Were the entire value of a water-course always to be measured by its service, as an avenue for "market-men," the conversion of its territory from commercial to agricultural uses would be generally popular as soon as the bed of the stream became more valuable to the farmer than its water, and no strife would occur; but in most cases there are other interests involved which are antagonistic to this change, viz: the trade in foreign or distant products, the fisheries, &c. Sometimes, too, an arm of the sea which has ceased to be of use to the residents upon its banks, has still a national value as a harbor of refuge or as a thoroughfare.

It might be supposed that a study of long-standing marine works, and the comparison of repeated surveys, would lead directly to generalizations relative to the effects of encroachments upon the pathways of streams. My experience, however, in such inquiries has been anything but this. The testimony, as a whole, is conflicting, and it is only by recognizing among streams generic and specific differences, and classifying all streams according to them, that I have any hope of formulating the results of my study. This hope is not yet fully realized, but I shall venture to suggest a few of the points I have reached.

Tidal and river currents.—Were there no other agencies at work than the tides, the form of channel which these would construct, in alluvial soil, would be the *estuary;* I use this word, because it is already understood to designate a water-way whose sections increase as they near the sea. If this increase of section were simply dependent upon volume, I might have used the term *conoid,* but scour depends directly upon the velocity of currents, and no symmetrical figure can represent a channel excavated by two streams, ebb and flood, which have different velocities and pathways.

1st. *A greater proportion of the scour of channels is executed by the ebb than by the flood, because the former is concentrative, while the latter is dispersive.*

I called attention many years ago to this contrast between the modes of action of the alternate tidal drifts, and illustrated their combined effects by such instances as Delaware and Chesapeake Bays. The tide-wave travels more rapidly in deep than in shallow water, so that in the middle of the bay the water is more elevated on the rise and less elevated on the fall than along the shore; the rise is therefore attended by a current pressing shoreward, while the fall induces a running in toward a central axis. The consequence is, that, although the inflowing and outflowing volumes may be equal, in a supposititious case, the ebb, *concentrated,* is the more rapid, and therefore plays the greater part in excavating a central channel-way to the sea.

2d. *Near the outlet of a tidal basin the section is greater, in proportion to the passing volume, during the flood than during the ebb, so that the latter is the more rapid stream, and confines its work more closely to the channel-way.*

This finds its best illustration in the case where a sandy channel communicates with distant and shallow interior basins. The flood has but little filling to do until a high stage is reached, and does not therefore acquire a high velocity. The discharge, on the contrary, of the interior basins is so delayed that the tide near the entrance has fallen off very much before the outflowing volume becomes considerable. In an extreme case the very volumes that pass up with the entrance channel nearly full escape to the sea again when this channel is nearly empty.

3d. *River currents, because less dense than the sea water, are disposed to become superficial on meeting the latter, and therefore execute little scour in their lower courses.*

The phenomena at the mouths of rivers emptying into tideless seas illustrate in a striking manner this thinning out of the river over the surface of the salt-water. Humphrey and Abbot's report on the Mississippi River states that "the current in the Southwest Pass is quite equal to pushing this material along the bottom, but when the river water begins to ascend upon the salt water of the Gulf, the rolling material is not carried with it, but is left upon the bottom in the dead

angle of salt water. A deposit is thus formed whose surface is along or near the line upon which the fresh water rises on the salt water as it enters the Gulf. *This action produces the bar.*"

Admiral Smyth found the waters of the Rhone overlying the Mediterranean three miles beyond the delta shore, but the depth of this fresh stratum measured only three feet.

We cannot attribute the formation of bars exclusively to the lifting of the fresh waters of rivers upon the salt waters of the sea, because there is a disposition in all streams to relinquish their debris wherever an enlargement of section causes a reduction in the velocity of the current, and this, of course, is most conspicuous at embouchures. The waves, in exposed situations, take also a prominent part, not only in breaking up the outflows of streams and in forcing back and heaping up their debris, but often in augmenting the supply of bar-building material by contributions from the wear of the coast. Thus bars are to be found at the mouths of rivers flowing into broad lakes which resemble those upon the seaboard, except that the former are less abrupt and of less elevation than the latter, other things equal. A comparison, however, of coast charts discovers that much the worst bars form where great rivers empty upon tideless seas; so that we may infer that in the meeting of waters a difference of density aggravates the case. All the streams flowing into the Mediterranean are closed to maritime commerce, and all the silt-bearing rivers which find their way into the Black and Caspian Seas are likewise stopped up. According to Sir Charles Hartley, over sixty per cent. of the waters of the Danube escape to the sea by the Killia mouths, over bars having no channels through them more than six feet deep.

River-waters perform so little service as scouring forces at the sea-board, that, in many instances where they have been found charged with sediments, engineers have advocated their exclusion from harbors. The Italian engineers, particularly, concur in advising against the choice of a river mouth as a site for an artificial harbor. So, also, the French engineers, in planning the ship-canal of Saint Louis, have provided for a gate to prevent the waters of the Rhone from flowing into the terminal harbor upon the Mediterranean. Judging from the condition of the natural outlets of the river, they believed that its water, if suffered to pass through the canal, would not only be of no service as a scouring agent, but an injury, because of the burden of mud which it would relinquish upon the threshold of the port.

The Mississippi bars remain at the same absolute elevations during floods as during low stages; and the Danube has a worse bar in the former than in the latter condition. The more effectually a river is able to exclude the sea from its basins, the more utterly impotent it seems to be in its last struggle to reach the ocean. I remember to have been much impressed with the fate of a torrent which I saw rushing from the Maritime Alps toward the Mediterranean. It was a deep stream, plowing its way furiously through the country till it reached the sea; there it received a sudden check, stumbled over its own debris, and broke up.

In my report upon "The Coast of Egypt and the Suez Canal," I called attention to the fact that, with other things equal, rivers with tides have more water upon their bars than those without. The effect of a flood-current is to bring in the sea and mingle it with the fresh river-waters, and thus give to the outflow a deeper scouring power; I may go further, and say that rivers, otherwise equal, have deeper bars in proportion to the amount of flood-current. Is it not a significant fact that the Rhine, with its great outflow of fresh water, fails to maintain a ship-channel to the sea, while, in the same neighborhood, the Scheldt, the Jahde, and the Elbe, have plenty of water on their outer bars?

The river is not in all cases, perhaps not in a majority of cases the world over, the immediate source of the materials forming its bar, but in the present discussion this makes no difference; and I consider the following an authorized

GENERAL RULE.

A river having a bar at its mouth will be injured as a pathway for navigation if the tidal influx is reduced by encroachments upon its basins.

In the above rule I have been careful to speak of the injury as the result of a *reduction of the tidal influx*, because, not only are there rivers where the inflow is nothing, or in small proportion to the rise of the tide, but in all arms of the sea, whether fed by fresh waters or not, the total tidal volume (the prism between high and low water surfaces) exceeds the inflow from the ocean, because

it is not high water at the same moment over the whole basin. In the Hudson, for instance, there are two co-existing tides, one of them occupying the space between the sea and Poughkeepsie, the other the reach of the river above. The tide of this upper reach is simply a propagation of the preceding tide of the lower reach. At the moment of high water at the mouth of the river, it is low water at Poughkeepsie; and at this instant the prism (which is wedge-shape, its base being the surface of the previous low water, irrespective of time) represents all that can have possibly flowed in from sea during the entire period of flood. The effect of an encroachment, as measured in reduction of inflow from the sea, is less and less as we go up the river, till we reach Poughkeepsie, where it becomes nothing. The entire tide above this point might be destroyed without lessening the flood-current at the mouth of the river.

In a study of rivers we soon discover that we must distinguish between those which escape to the sea through fiords, and those which form their own beds or break through barriers of sand upon the coast. The former are usually without bars, the latter never. The tide plays so small a part in modifying the original features of the fiord that upon the coast of Maine, where the rise is great, we find harbors and channels resembling very closely those upon the western shore of the Baltic, where there is no tide whatever. It is only the smaller fiords that have filled up with river deposits and with sand washed in by the waves; in most of the larger ones the debris have accumulated only in the sheltered angles and basins. The form of the fiord, expanding its section as it approaches the sea, is favorable to the *gradual* deposit of sediments, whether these are brought down by the river or swept in by the waves. There is, however, no abrupt meeting of fresh and salt water, and no sudden slacking up of river or tidal currents at the sea border, so that outside bars do not often form. In its upper reaches the fiord is often obstructed, because its antecedent inequalities of section have induced the river, in establishing its regimen, to fill in the angles on either side and to raise the bed where the width was great. In such places the diking in of lateral basins, and the contraction of the water-way at some points, may be attended with good results. The history of the Thames shows how steadily the river has improved as the reclamations of its shores have proceeded. The Clyde, also, increased its depth as the levees of rubble were constructed, and without causing injurious deposits elsewhere.* In both of these cases the general form of the estuary was not changed. The walls on the two shores were built so as to diverge from each other, very much as the natural shores had done, except that re-enterent angles and irregularities were covered up. In strong contrast with the good effects of parallel works which we have cited, are the injuries done by bridges and other transverse works, both upon the Thames and Clyde.

The dikes or dams resorted to for purposes of reclamation belong to two orders, which may be designated as *parallel* and *transverse* works; the former comprising all those which follow along the margin of the stream, the latter those which cross the stream from shore to shore.

Parallel works.—These are of the two kinds, "insubmersible" and "submersible," the former wholly excluding the tides, the latter permitting the overflows for the sake of inducing deposits of sedimentary matter by a process known as "warping."

The general rule we have stated as applicable to harbors having bars must be received with certain limitations, because the degree of injury done by an encroachment depends very much upon the location of the work and its extent. If we compare charts of different sea-ports together, and select those which agree in the yielding character of their beds, in their exposure to the sea, and in their tidal and river volumes, we still find the facilities for navigation unequal, and conclude that the active forces are not equally useful—that some parts are *out of adjustment.* In such cases the way to improve upon natural conditions is obviously to enlarge one basin, reduce another, &c. There are flats too near and others too distant for useful reservoirs; those very near discharge their tidal volumes in advance of the great outflow from above, upon which the scour over the bar mainly depends; and those too distant do not communicate, by the fall of their tide, a motion to the waters at the mouth of the stream till too late for re-enforcement.

The element of distance also enters in another way, viz: the ebb current, flowing off from shallow flats, does not communicate at once its motion to the whole mass of the water in the channel, but for a considerable distance does little more than simply quicken the surface-drift. I

* Before dredging commenced.

have shown this by observations, and am satisfied that high flats near the mouths of estuaries may often be reclaimed without injury to the bar, provided the range of the tide in the river above is not thereby diminished. Those flats are the most useful which discharge their volumes of tide in season for reinforcing the *maximum outflow* upon the bar, and which run dry early enough to prevent a continuance of outflow at the bar after the tide has begun to rise in the sea. As we move up a stream, then the value of flats, in their physical relation to the bar, alters materially, depending upon their elevation from point to point, so that finally we reach so distant a point that those flats only which are covered by the highest spring tides have usefulness as reservoirs of power for the scour of the bar-channels. I would not be understood to say that those particles of water in the reservoirs which themselves reach the mouth of the river in season for co-operation in the scour are alone useful, but those alone whose *transmitted pressure* shall reach the bar and quicken the outflow at the proper stage. Each case presents a problem which may be satisfactorily solved after a proper gauging of the stream.

In Europe the effects of reclamation along the borders of tidal streams have been very far from uniform. The diking-in of marshes, and the closing of canals behind Ostend and L'Ecluse, destroyed those ports, but the diking of the Scheldt has not affected its outside bar, that I can learn. In England some outside bars have been made worse by parallel works excluding tide-water, and this has led the city of Liverpool to guard with jealousy the great reservoir above that city, the filling and draining of which maintains the channel-ways over the bar at the mouth of the Mersey. On the other hand it has been thus far a gain to navigation in many European rivers to fix, by reclamation, the shifting muds and sands near very shallow river mouths, like the Seine, La Vire, the Weser, &c.

Perhaps in this connection I cannot do better than quote the testimony of the highest authority, Thomas Stevenson, esq., who, in his work on the "Design and Construction of Harbors," says:

"From a comparison made many years ago of different low-water sections of the estuaries of various rivers, and also of bays and creeks in their state of nature, I found that *the low-water sectional areas increased directly as the quantities of tide-water that lay landward of each section-line.*

* * * * * * * * *

"The importance of preserving intact the capacity of the upper portions of rivers ought never to be a matter of any doubt, for although it be perfectly true that contraction benefits the navigation at the place where it exists, the effect cannot be otherwise than detrimental to those lower parts of the estuary, including the bar, if there be one, which are in every respect the most important. It has been often proposed that large tracts of land should be reclaimed on the upper portions of rivers, and it has been argued that the channel so constructed will, of course, become deeper than it was before. From calculations subsisting between the low-water sectional areas and the amounts of tidal water lying landwards of the section lines, I found that, in the narrow artificial channel of the river Dee, Cheshire, the efficacy of a given quantity of tidal water was greater than in navigations which were left more nearly in a state of nature. But, as already stated, the effect of excluding water being prejudicial to the lower reaches, ought to lead us to other means of improvement than the erection of such high bulwarks.

"The effect of low-water training-walls which do not confine the strength of the current, but simply guide the first of the flood and the last of the ebb-tide, are now well known from their extensive employment, as, for example, on the Clyde, Ribble, Lune, Nith, and other rivers."

If it becomes necessary in any portion of a tidal stream to improve the depth of the channel, this should be done by first removing the material with a dredge, and then contracting the low-water space by submersible dikes or training-walls. If the locality requiring improvement is low down the stream, so that half-tide dikes will be exposed, while the discharge from above is still active, they will really accomplish as much as levees, and without incurring any injurious loss of tide on the bar. In the Elbe, below Hamburg, there had existed since an unknown period a shoal, which the city finally decided to remove by dredging, and did so a few years ago. This shoal has, however, formed again, and, what is most curious, the new shoal is of sand, whereas the old one was of clay. The case presented was probably that of a neutral spot, where, below a certain depth, the forces (flood, ebb, and river outflows) were in equilibrium. A physical survey would have detected this and saved the waste of labor. In order to preserve an artificial depth, a new direction

or energy must be given to the stream by proper dikes. Many persons look at the bar at the mouth of a river as the result of long accumulation and gradual accretion. Lamblardie computed the age of the Trouville Shoal in the estuary of the Seine at three thousand years. My own experience of sandy shoals is that they have no such history; the shifting bottom arranges itself in hills and valleys precisely as the active forces will permit, and a sand-shoal removed by the dredge will be restored almost immediately. I have seen shoals in North Carolina that moved bodily to and fro with every tide, preserving the same height and much the same figure from day to day and from year to year. The attempt of the United States Engineers, many years ago, to cut a channel-way through the bar of Nantucket Harbor, utterly failed; it was like baling out the sea. In studying the sand-banks of New York Harbor, I showed from observations that they lay in the equilibrium points among the tidal currents and waves, and I think most of them would form again in a week if suddenly swept away.

As we have seen, levees are open to the objection that they diminish the tidal influx and reflux; this objection does not hold against submersible dikes or training-walls, which, as far as I can learn, have been equally successful as means of improving the local depths of channels. Notable instances of their success are offered at the Helder, in the Seine, the Thames, the Dee, and in the Clyde.

It is especially in the lower courses of tidal streams that training-walls are effectual. They do not essentially diminish the volume of tidal inflow nor quicken the flood-current. The greatest volume passes into a tidal river after the tide has risen half its height, or when the training-wall is submerged and escapes into the sea again after the tide has fallen below half-tide, so as to uncover the wall, and confine the ebb-stream, now much quickened, to the channel.

In the case of the Clyde, not only were training-walls built *below* Glasgow, but obstructions, caused by weirs and bridges above, were removed or reduced, so that the tide made a longer inland journey. The opposite course was pursued by the French engineers in their attempts to improve the Adour. Upright walls of masory were built on either side of the river, slightly converging as they reached the sea, and the consequence has been a reduction of the tidal range at Bayonne, and no improvement, except that the bar-channel no longer shifts its position. Efforts are being made to carry these walls out beyond the bar of the Adour, but few believe in the ultimate value of this costly work.

The construction of submersible dikes is often resorted to in connection with projects of reclamation, but not always with the design of ultimately raising these works so as wholly to exclude the tide, although the direct object is always to induce accumulation by a process called in England *warping*. In the low countries of Holland and Germany warping is resorted to for the sake of creating fore-shore protection of reclaimed lands. Beyond the main dike a low parallel wall of rubble or fascinage is built, at a distance of a few hundred feet, and the inclosed space divided into pens or catch-basins, to be filled with sediments at the high tide or during river-floods, when these walls are submerged. The Prussian government has provided in this way for the future protection of the dikes in the neighborhood of the naval station at Heppens on the Jahde.*

On the banks of rapid streams, or those subject to floods, fore-shore protections outside of the dikes are absolutely indispensable. These are frequently provided by constructing groynes or jetties of rubble or fascinage, but these are objectionable, not only because they disturb the flow of the stream, creating eddies, &c., but because they are really poor economy, since in the course of time they have to be increased in number till they consume more material than longitudinal training-walls. Weibking says that the experience of many years upon the Rhine has shown that groynes for fore-shore protection must not be more than their length apart. On the Clyde groynes were originally resorted to, but ultimately it became necessary to connect the outer ends of these by training-walls. An exceptional case is offered by the tidal river Tees, where groynes have been used with decided success.

Transverse works.—Weirs and sluice-bridges involve all the objections that we have offered against encroachments upon tide-water, since they completely arrest the progress of the tide. The testimony of history is decidedly against them, and I shall content myself with simply quoting

* The portion of the Jahde in front of these dikes was the scene of the grand slump in the sixteenth century. Men-of-war maneuver now over the sites of ancient villages and farms.

notable facts from the highest authorities to which I have access. In doing this it will not be necessary to distinguish between works thrown across streams for the purpose of elevating the back-waters, and those constructed for drainage, since in their effects upon the lower reaches they do not differ. Bouniceau, in his "Études sur la Navigation des Rivières à Marées," declares that transverse dams ought to be proscribed in the maritime portions of rivers—that "their existence is only injurious to navigation." He cites the cases of the river Aure, which had been shoaled over three feet by the effect of a sluice-bridge, and of the approaches to Isigny, which were sanded up in consequence of a sluice-dam across the Vire. The council of the Ponts et Chaussées recommended the removal of this sluice-bridge, declaring that it had destroyed maritime navigation, because, being furnished with gates, it had hindered the oscillation of the flood and ebb. The obstruction was removed and the tides resumed their good offices as of old. Mr. Cordier, in 1828, wrote the following opinion concerning the effects of sluice-dams above the Port of Dunkerque: "Twice a day the tide inundated the vast plain of Walteringues and twice retired, so that this port was traversed four times per day by an immense current, which opened the channel and maintained the passes from the roadstead. Since the construction of this sluice-dam, natural scour has ceased, and deposits have closed the entrance to the port. The shore, which extends itself more and more, has become continuous, and the passes from the roadstead have shrunk up." Again, with regard to the sluice-dam at Gravelines, the same writer says: "The same movements took place at Gravelines; the sea submerged the territory as far up as St. Omer, at that time accessible to ships, and covered twice a day a plain many leagues square; a broad and deep channel was maintained from Gravelines, and the creek, opened at the foot of the dunes from Gravelines to Dunkerque by the natural scour, favored the navigation and contributed to the amelioration of the two ports; the sluices of Gravelines have changed these conditions, the sea has been held back, the channel is filled up, and this port, formerly very good, is essentially lost."

De Prony favored only a sluice-dam upon the sea-margin, where it should form a continuation of the coast and leave no angle of repose for sands to gather. He had observed that the gravel traveling along the north coast of France rested nowhere except in sheltered angles, the mouths of rivers, &c. I conceive that this distinguished savant had in view only the navigation of the Seine, and believed that if the weir were not placed at the very mouth of the estuary, the sand would so accumulate below that the approach for ships from sea could not be preserved. Precisely this has been the experience at Boston, (England.) Smeaton built the Boston sluice with the expressed design of keeping out the tide-water. In 1720 vessels of two hundred and fifty to three hundred tons (the largest then in ordinary use) could run up and discharge at the quays. Now, in seasons of low river water, the sluice-gate has ten to eleven feet of sand piled up against it on the seaward side. Rye Harbor suffered the same way. A sluice recently constructed on the Nene, fourteen miles from the sea, proved such an injury that the mob tore it up two and a half years after its erection. The sand accumulated below the sluice, but on the removal of the structure was at once swept away by the tide. The old Rhine, passing through North Holland, had been gradually narrowed down by reclamations till its natural outlet could not be sufficiently preserved, even for drainage purposes, and recourse was had to De Prony's plan of constructing the sluice of Katwijk at the margin of the open sea. Commenting upon this, a writer in the "Engineer and Architects' Journal," 1846, says: "The fate of the old Rhine has been aptly compared to that of a dethroned monarch, who is deprived even of the satisfaction of attracting admiration and sympathy by the grandeur of his exit."

The first effects of a loss of tidal volume is usually a narrowing of the channel below rather than a diminution of depth along the channel-way. This seems to have been the experience in Boston Harbor, Massachusetts, and very conspicuously in the North River, Massachusetts. In this latter case an overflow of the sea, during the Minot's gale of 1851, constructed a shingle-bar across the stream about a mile above its mouth, thereby shutting out three-fifths of the tidal volume which formerly passed up. The recent surveys show that as a result of this loss the channel below the obstruction has gradually declined in width, especially at the mouth, while the central depth has remained essentially the same.

The history of the Humber, which upon positive data extends back to 1684, furnishes the most remarkable instance that I can cite of a first-class port that has been damaged in its approaches

by loss of tide-water due to reclamations. In the earliest reliable charts, ten, eleven, and twelve fathoms could be tracked in from the sea, and the narrowest place in the approach to the shelter of the estuary was one and a half miles between the five-fathom curves, and no outside shoals existed. Now the principal dangers lie two miles outside of the shelter, where a narrow channel of five fathoms (marked by two light-ships) meanders among shoals of sand. In the interval between the two periods, the original four hundred square miles of tidal area has been reduced to one hundred and ten.* My own experiments in New York Harbor, at the mouth of the Hudson, showed, from sub current observations, that an increase of fresh-water discharge did not increase but really diminished the seaward scour on the beds of the deep channels; and it was inferred that in the dry season, when the sea-water was carried higher up the river, a deeper flow of the ebb was induced because of the greater density of the water. I have followed the sea-water along the bed of the Hudson forty miles above its mouth.

Physical history of salt-marshes.—In what I have heretofore said of the relations of currents, &c., to the channels which they traverse, I have drawn upon my experience and studies with a degree of confidence; but in the comments which I now propose to make upon the origin of the salt-marshes I enter upon a subject rather new to me, and although I shall still confine myself as closely as possible to the results of observation, I am not at all tenacious of my inductions, but offer them with the hope of eliciting better information upon the subject.

To my mind, the salt-marshes along our coast are not fully accounted for under the terms "*glacial paste*," and *river debris*. They do not appear to me as detritus from the interior, but, in the main, as products of the waste of the coast. It is not only at the mouths of rivers, or at the bases of great continental slopes that these appear, but we find them in coves and dead angles of the shore, wherever the coast is falling back before the dash of the sea; not only upon the borders of the main-land, far from any considerable issue of land-waters, but also upon islands wide out at sea, where there is scarcely any water-shed.

When a headland crumbles down in the attack of the waves, the materials are assorted almost immediately; the coarse sand, gravel, and stones are strewn along to form the *littoral cordon*, but the finer materials are held in suspension till they find opportunity to settle in sheltered places, perhaps under the lee of the cordon itself. Upon our New England shore I distinguish, as the result of this sifting action of the sea, three distinct categories, viz: beech-sand, shingle, and marsh-muds. The separation among these results from their different sizes and weights, which give them different rates of travel along the shore, under the action of waves whose directions are oblique to that of the general coast-line. The angles and coves are cut off and formed into bights, and ultimately into lagoons, by strips of beach which cross them, and upon these strips of beach shingle-levees form at a later period. As the construction of this breakwater progresses, the basin within becomes tranquil, so as to admit of the precipitation of the suspended material forming our third category, and the marsh begins to form under the protection of a natural dike. The littoral cordon thus created has a tendency toward complete closure, since the constructive power of the waves is often out of all proportion with the scouring action of river and tidal currents. These lagoons at best can preserve but narrow outlets, and very often these are closed for long periods—long enough for the marsh to freshen, and, perhaps, become grown over with forests.

The material that would remain suspended only so long as the agitation of the sea continued must be of limited range, and if of uniform character,(quartz sand, for instance,) it must be of almost uniformly small size, because the waves can only suspend those things whose weights are in small proportion to their surfaces. We ought to expect to find in the sediment within the littoral cordon great homogeneity if these are products from the waste of the coast, and we do find that marshes possess this character generally.

Professor Agassiz and others have called my attention to the fact that, at considerable depths under some of the salt marshes, deposits of peat are found. I offer the suggestion that this deposit, antecedent, of course, to the superimposed marsh, is antecedent also to the order of circumstances under which the material from outside has found its way to the same resting-place. I have, in a preceding portion of this paper, spoken of the *narrowing* of harbor channels, which often precedes

* See Shelford on the "Outfall of the Humber," Vol. XXVIII. Proceedings Inst. Civ. Eng.

any central shoaling. Specimens from the most depressed portions of channels often reveal the character of the deposits antecedent to those taking place at the present time. In Boston Harbor, a deposit of peat is said to exist by Mr. Bosehke, who has been dredging in the axis of the main ship-channel, where no accumulations within the last century (at least) have occurred.

Upon the beds of quiet basins vegetation plays a constructive part. The *Zostera marina* (eel-grass) arrests and fixes the sediments of the sea very much as the beach-grass catches the flying dune-sands upon the shore. In the *Petite Rade* of Toulon, an elevation of the bottom, two and a half feet in the average in thirty years, was attributed to the luxuriant growth of eel-grass of a species closely allied to our own. We observe the same thing in our own ports, and should expect the filling up of a basin to go on till the whole surface is above the ordinary reach of the sea.

When the subject of reclamation of tide-lands was first proposed to me as a theme, I considered the initial step was to ascertain the elevations of the marshes. This led me very quickly to the discovery that their nearly horizontal surfaces are at the *plane of mean high water*. I compared the marshes on the two shores of the narrow isthmus between Cape Cod and Buzzard's Bays, where we had careful connecting lines of levels and good series of tidal observations. I found that the marshes on either side differed but about one-tenth of a foot from the local elevation of mean high water; so that we have here, within six miles of each other, two systems of marshes, differing in elevation as much as the planes of high water, *i. e.*, the marshes on the Cape Cod Bay side are two and a half feet higher than those on the Buzzard's Bay side. I then inquired into the levels of marshes high up in the Bay of Fundy, and computed, from some levelings made by the Royal Engineers, that the plane of the marshes lies about half-way between the high waters of springs and neaps, or at the mean high-water plane. So, in San Francisco Bay, as well as I could judge from a short series of observations, the marsh-plane is the ordinary high-water level. It appears, then, that the sea has exercised an important control upon the marsh, and this is circumstantial evidence that these marshes belong to the present tidal epoch, and that the sea has played an intimate part in their formation.

Leaving out of the question the deltas of rivers, it is a fact, well known to practical engineers, that deposits of sediments take place in harbors and docks, and that the amount accumulating in tidal waters is much greater than elsewhere. According to Minard, (as cited by Stevenson in his work on harbors,) the sedimentary deposit in basins along the almost tideless shores of the Mediterranean, is not one-sixtieth part as great as in those similarly situated on the Atlantic and North Sea.

This testimony of Minard is, no doubt, an exaggeration, because it is based upon docks, &c. If channels alone were compared, the results would have been quite of an opposite character. In tidal harbors the deposits are not uniformly distributed over the bottom; the channel-ways are swept out by the currents, and the angles of the shores filled up. My own comparison of the charts of the Mediterranean with those of tidal seas confirms me in this view, and I can but regard the tides as exceedingly valuable agencies in preserving the avenues of navigation. In some of our ports, in New York, for instance, channels that are hourly traversed by steamers are gradually deepening, because the bottom is stirred, so that the tidal current can bear away material which it could not otherwise lift.

Let us now inquire if there is any evidence that the marshes are increasing, and whether this increase is particularly striking in neighborhoods where the coast is wearing away. I could furnish some small instances of growing marshes in our own country, but I think it safer to refer to the changes in the Old World, where the comparative surveys cover several centuries, and where remarkable cases have attracted observation. To European engineers the increase of certain marshes is a fact so well recognized, that methods have been devised by them for lending aid to nature in this formation of new lands. These methods are known in England under the general designation of "*warping*," which I have already referred to under the head of "parallel works." In comparing the results reported by engineers of different countries, I was not surprised to find that the success of warping near the coast has been very unequal in different localities, and that, with other things the same, it is greatest in neighborhoods where the coast is falling back. Warping is employed in Holland to add fore-shore for the protection of the dikes, but would not

pay simply as a means of reclamation in the mouths of the Rhine, where the yearly deposit is but a thin film. In the estuary of the Humber, on the other hand, the warping is wholly for the enlargement of agricultural districts. For distances of forty miles above and below the mouth of this stream, the coast has fallen back ten feet per year, according to the different surveys since 1684, which represents an enormous volume, because the coast is generally high, (thirty to forty feet.) The recent growths of the marshes in this estuary are attributed to material from outside by Professor Philips in his "Geology of the Yorkshire Coast," and seems to be the only reasonable way for accounting for such enormous deposits at the mouth of so small a river. For instance, Sunk Island, near the mouth of the estuary, which, in the time of Charles First, contained nine acres of diked land, now has seven thousand acres under cultivation, and covers the site of a twelve-foot channel as given on several early charts.* The warping practiced in this estuary accomplishes generally one foot of elevation per annum, although Coleman's "European Agriculture" mentions a case of "ten or fifteen acres warped to a thickness of one to three feet during ten to twelve tides." I find in these accounts of the Humber estuary that the greatest deposit within the submersible dikes is during the dry season. This I consider a significant fact, indicating that in proportion as the flood-current (bringing sediments from outside) is of long duration, the warping succeeds. Ferdinand de Lesseps, in one of his early reports,† attempted to discredit the ancient idea that *the delta is the gift of the Nile*, and in this absurd endeavor he cited some collateral evidence which serves my turn better than it did his. An analysis of the deposits in the Bay of Saint Michel shows that the material is from the adjacent coast, which is retreating. An examination in the Seine showed that the river debris did not extend below Rouen, and that the shoals forming in the estuary below were from the wear of the coast.

Warping is practiced with success at the head of the Bay of Fundy, where extensive marshes have been reclaimed. The flood tidal current brings with it great burdens of mud. Here the narrow isthmus affords no considerable water-shed, and the water evidently owes its turbid character to the rush of the tide along its bed, and to the wear of the shores below. Even at our southern inlets, where the sifting operation would seem to be finished, and where the cordon would seem to have reached a state of equilibrium, the flood-current and the water pushed in by the rush of the sea is often milky with the quartz-dust which the grinding breakers supply. From the very nature of the flood-current (divergent) it presses upon the coast and receives for transportation all the waste of the shore, and all the fine material ground up by the breakers. The "bulkheads" within our southern inlets seem to be composed of the fine sand brought in from outside, while the outer bar is but the mass of material from the site of the inlet itself. In some of the lagoons of the Mediterranean shore, warping is practiced upon waters that flow in from the sea.

Along some coasts there is a mass of material traveling along shore and ready to seek rest in any cove or shelter, especially where encouraged by the flood-current, which, as I have said, is eminently a coastwise stream. Lieutenant, now Admiral Davis, first called special attention to the constructive character of the flood-current, in his articles before the American Academy, upon which I shall hereafter have occasion to comment.

According to Bouniceau, (*Etudes et notions sur les constructions à la mer*,) to bring the strand to the level of high water by warping, requires twelve years in the estuary of the Seine, thirty in the bay of Vays, and eighty in the Sheldt.

The littoral cordon is a developing physical phenomenon of the coast, distinguishing peculiarly, I think, the present geological period, and perhaps the most interesting and important among the changing features exhibited by our comparative surveys. It appears upon our New England coast as isolated strips of beach or shingle levees, crossing the mouths of fiords and coves; but upon our southern sea-board it is the grand characteristic, and is almost continuous from Montauk to the coral reefs of Florida, and from St. Marks to Yucatan.‡ Except at Long Branch, I can remember no locality below Montauk where the antecedent drift-formation reaches

* Shelford.

† "Percement de L'Isthme de Suez. Exposé et Documents Officiels, 1855."

‡ Although the reefs of Florida may be similar formations, veneered with the coral growth, the proof is wanting to sustain this conception.

the sea, and I conceive that those long rifts, like Hatteras Banks, which lie many miles from the main-land, occupy what was (perhaps at the time the glaciers melted) the breaker-line upon the shallow bank which formed the submerged prolongation of the continent, which has here but a slight inclination toward the ocean. This windrow of sand I believe to be very gradually falling back; the fine sand ground up by the sea is caught up by the winds and formed into dunes, or forced through the inlets by the rush of the waves and flood-current, to be converted into flats and marshes.*

The tendency of the natural forces now operating upon the coast seems to be toward a complete smoothing away of all the indentures of the shore-line. I use the word *indentures*, because I would not imply that great bends and gulfs are to disappear. We are naturally prone to the belief that what we call the orderly activities of nature are working out an equilibrium, and this has induced a prevalent notion that the sea is robbing the continent of material to fill up the inequalities of its bed. As far as my observations have extended, there seems to be little ground for this notion, and I am inclined to think with Rear-Admiral Davis that the sea "ejects or repels" the debris of the continent that would fall into its bosom.† I do not agree with the savan whose words I have quoted, in giving to the flood-current the principal part in the "ejection" of materials, and it seems to me that the evidence he cites bears witness rather to the action of waves than to that of running water. It is a familiar fact that waves running over shallow ground acquire a real motion of translation. The passing of a wave as felt by divers, standing upon the bottom, is a sudden jerk toward the coast. The water that would thus pile up against the shore is carried back into the ocean by a general and continued current. The movement toward the land is in very short but very rapid dashes, while the return is more gentle and steady. In this contrast of velocities between the onset and the retreat of the sea, lies, I think, the true cause of the accumulations upon the coast and the tendency of heavy bodies, like the coal from steamers, &c., to come on shore. When we consider that the *work* done is proportional to the *square of the velocity*, and that the *weight* that may be moved by running water varies with the *sixth power of the velocity*, we certainly may expect the changes along the coast to reflect rather the action of rushing waves than feeble currents. My own observations along the coast of Long Island showed that an eastwardly current prevailed, but that the sands near the beach moved before the sea to the westward. Under circumstances arising from the peculiar configuration of the shore, or from its exposure, the waves at some points along the coast are prone to run very high, and develop great transporting power. It is particularly noticeable that gulfs and bays which open in the direction from which heavy gales frequently blow, are extending without any diminution of average depth along their axial lines, except where rocks resist for a while the wear of the sea. As an example, and a good one, because resting upon positive knowledge, I offer the case of the Gulf of Gascony in the neighborhood of *St. Jean de Luz*, where repeated surveys show that the submerged contours are falling back, and the bay actually extending and deepening. The material scoured away is ground up fine by the waves, cast upon the beach, and finally blown away in dunes toward the interior.‡ The bight of Cape Cod Bay below the Plymouth Entrance bears every trace of an encroaching sea. The water is bold close in-shore, so that a man-of-war may ride at anchor within what was probably the base of the high hill, whose remaining portion bears the name of Peaked Bluff. The waves have carried none of the material seaward, (of this we are sure from the character of the bottom,) but have swept it along shore to the eastward, the fine sands to be formed into dunes, and the shingle to be moved on and accumulated until it shall become equal to the protection of the shore by resisting the onset of the sea.

I have not, in our repeated surveys, seen the slightest evidence that the material of the falling bluffs of Boston Bay are borne out to sea; I think the harbors and coves have received it all. The ebb-tidal currents seem to have kept the channels sufficiently free, and may have carried out to sea some very light substances, but we do not find them deposited there.

In addition to the erosion which great tides induce, the wedge shape of the Bay of Fundy is

* I am indebted to Colonel Grammar, of the Massachusetts Harbor Commission, for positive data relative to the falling back of Hatteras Banks.

† See memoir of Lieutenant Charles H. Davis, Fourth Volume, (new series,) American Academy of Arts and Sciences; also, Smithsonian Contributions of 1851.

‡ From a lithographic copy of a report furnished to me by the author, Boquet de la Grye, hydrographic engineer of the west coast of France.

no doubt peculiarly favorable to the augmentation of the carrying powers of ordinary waves driving in from the sea, and to these combined actions I attribute the turbid state of the waters near the head of this gulf, where the tide is so laden with sediments that warping is successfully practiced.

Mr. A. Savary, an engineer residing at East Wareham, has written me an able and very interesting communication concerning Buzzard's Bay, in which he gives me the results of observations, some of them stated numerically, which show that the sheltered basins at the upper end of the bay are filling up with sand and stones torn from headlands below, which are wasting under the action of the waves during southerly gales. Some of these basins, he says, are used for planting oysters, and, from his own experience, states that after a gale the oysters are always found higher up the stream. He, however, attributes this movement altogether to the flood-current,* and makes it dependent upon the depth of superincumbent water, a conclusion that seems to be opposed to well-established laws of hydrodynamics, although I am aware that some English engineers of eminence, among them Mr. Calver, still insist upon making *weight* an element in the friction of running water.

The views I have entertained relative to the restoration to the continent of all the material washed from its bluffs and headlands by the sea, must be modified when we come to consider islands. Where these are crumbling down under the action of the waves, we usually see a loss upon the windward shore, and a reappearance of the material upon the leeward side. Sometimes we find two hooks extending leeward from either end of a wasting island, as in the case of Nantucket, and these hooks, in other cases, unite under the lee and inclose lagoons, which ultimately become, perhaps, marshes. High islands may thus gradually be converted in low atolls, (if I may use this term,) which occupy more than their original share of the ocean bed. There are, however, many cases where the wasted material does not reappear, most prominent among which is the familiar instance of Helgoland, a lofty island, which was once many times its present area.

A fringe of salt-marsh is sometimes seen along the coast, outside of the littoral cordon, showing that the latter has been forced back over the marshes formerly lying within its protection; and, as this outlying marsh is seen only at very low tides, in most cases, it has been cited as an evidence of a general submergence. I suggest that the falling back of the heavy natural dike over the marsh may have depressed the latter, or where this has not occurred, that the sea has undermined the marsh and let it down. No earthy material resists the action of the sea better than salt-marsh; but below the vegetable soil, at a considerable depth, there is often quicksand that might easily be washed out by the sea. I know of an instance where a very high dune, in falling back from the coast, left exposed beneath the sea an old salt-marsh, upon which it had been resting for many years, and which it appears to have crushed down by its weight. On the other hand, the shingle-levee on the Scituate shore does not depress the marsh as it rolls back over it, although the weight is over 1,500 pounds to the square foot.

After inclosure and drainage, salt-marshes usually sink, sometimes largely by their own weight, where the substratum is peat or quicksand, and sometimes only the amount due to shrinkage. Slumps of twelve feet have occurred in Holland. The Bisch-Bosch, and a large part of the Zuyder-Zee, lie over ancient folders. It may be that marshes have sometimes dried up and sunk after the natural closure of the "littoral cordon," and again, after a long period, have been exposed to the sea by the destruction or falling back of the cordon. I have seen no case of submerged marshes that seems to me to be worth much in support of a theory of general submergence.

Most of the marshes along our coast, like those of the Netherlands and the west coast of Denmark, lie within the "littoral cordon;" and in the course of the practical operations of the past season, which form the subject of the second part of this report, I have been led into special studies of the shingle-levees. These natural dikes have some characteristics which are general and deserving of comment, I think, aside from their particular bearing upon projects of reclamation.

Shingle-levees.—English observers are pretty well agreed upon the following characteristics of shingle-levees:

1st. The largest pebbles are found upon the summit and farthest from the source of supply.

2d. The fore-slope is a series of "fulls" or berms.

* Very much the same view that was expressed by Lieutenant Davis.

To these rules or general point of resemblance, my own experience adds the following:

3d. The seaward slope, near the crest, is 3 : 1, while the mean is 5 : 1.

4th. While upon the one hand the fore-slope is diversified by *horizontal* fulls or berms, the rear-slope, in striking contrast, is an alternation of *vertical* furrows and buttresses. The front face takes the form best calculated to resist the attacks of the sea, while the rear side takes the form best adapted to the rapid escape of overflowing water, as far as this is consistent with the security of the base.

The best explanation that I have seen of the first rule above stated is implied in the following quotation from Palmer's paper in the Phil. Trans. of 1834: "In all cases we observe that the finer particles descend the whole distance with the returning breaker unless accidentally deposited in some interstices, but we perceive that the larger pebbles return only a part of the distance; and upon further inspection, we find that the distance to which each pebble returns bears some relation to its dimensions."

The sea, in its onset, is an irresistible force, which, upon its sudden destruction, would leave a wall of stones, mingling all sizes and weights indiscriminately. The reflux or *undertow*, however, carries back the smaller stuff, and forms with it a talus slope. We see, then, that the average size of the stones should be greater near the top, and that the fore-slope should be less and less steep as we go down to the foot. It has been suggested that the breaking sea is an explosive force, and that, therefore, the larger stones should go further than others; but my observation has been that there is no assorting process in the breaker, but simply a *selection* in the recoil.

If the height of the levee is in proportion to that of the storm-sea, we should expect that the slopes of all levees of the same material would be in the same order under the above theory, and this is my experience thus far in this study. The slopes are those of repose in running water.

Caland constructed the great dike of West Capelle under the conviction that the action transmitted by the shock of the waves should vary with the square of the height of the water covering the talus, and that the base of the fore-slope of a dike should be in proportion to the square of the height.* I cannot find in nature any rule of construction like this. In the comparison of shingle-levees of different heights, I find the slopes constant; in other words, the base of the fore-slope varies with the first power of the height.

I find from my notes that on the occasion of my visit to Petten, North Holland, Mr. Conrad was busy in pitching the fore-slope of the great dike with basalt blocks at slopes of 3 : 1 and 5 : 1, but in the reverse of the natural order, *i. e.*, he placed the steeper slope below the other. This seems to have been a form arrived at from several centuries of recorded experience.†

The fulls or berms, which appear upon the seaward face of the natural dike, are miniature levees, thrown up by the lesser storm seas and superimposed upon the main structure. They add to the security of the dike, since they serve to break up the sea. It is a fundamental idea, already fully recognized by engineers, that the difficulty and cost of building a wall that will resist at once the dash of the breakers, is out of all proportion with the facility with which the attack may be resisted by a succession of obstacles. I was shown, in 1868, an artificial structure in the form of a *stairway* upon the shore of Medoc, which was said to have withstood the shock of the great seas of the bay of Biscay better than anything yet devised. So, also, as a parallel to the form of the rear-slope, I find in the cuts of railways that the sand-banks on either hand do not reach the conditions of proper drainage and repose, so as to be permanently covered with grass, till corrugated or furrowed vertically, and I have seen cases in France where the skillful engineer, anticipating the slow processes of nature, put his slopes at once into this permanent form.

Other natural levees.—The general rules I have laid down apply to *shingle*-levees exclusively—that is to say, to those levees which are composed of stones rounded and water-worn. Occasionally levees of angular stones are met with upon our coast, and I have seen them in the Bahamas composed of shells, and on the lake shores of drift-wood. The slopes and heights vary with the different materials in a manner that I do not yet understand. At Nahant there is a short levee of angular blocks broken from a projecting ledge near by, the largest pieces being at or near the

**Essai sur les Travaux de Fascinages, par U. N. Kümmer.*

†See *Verhandeling over de Hondsbossche Zeewering door I. F. W. Conrad, Ingenieur de I ste Klasse van's Rijks Waterstaat.*

summit, where they occasionally measure over three cubic feet each. The height of this levee is about 0.75 of that of the shingle-levee in the same neighborhood, and its fore-slope is less abrupt. Professor Agassiz has furnished me with evidence of the very recent origin of this levee, which I shall quote hereafter.

Perhaps the most singular freak of the sea in the way of dike-building is to be found upon Salt Key, one of the smallest of the Bahama Islands. Here occurs an almost perpendicular wall, about twelve feet high, consisting wholly of *conch-shells*, nearly all of them perfect. One might suppose from the uniform height of this wall, and its perfect alignment, that it was a work of art, except that to build a "dry wall" of conch-shells would rather puzzle human ingenuity.*

In my past season's work I have measured several levees, for the purpose of ascertaining how high the seas run upon the coast; the overflow of these being rare and notable circumstances to the persons in the neighborhood. In the second part of this report I have given the elements for profiles of sections. The fore-slopes, where the material is shingle, have been 3:1 for maximum and 5:1 for mean.

The highest shingle-levee in the world is Chesil Bank, on the south coast of England, in a situation peculiarly exposed to the violent seas that rush into the channel. Its height varies from twenty-three to forty-three feet along a distance of ten miles. The inclination of the fore-slope in the most perfect part of this levee is 5:1.

Upon the borders of the Bay of Audierne, in Brittany, there is a shingle-levee nearly eight miles in length, whose average height is sixteen feet—the same as our levee at Scituate, and, like the latter, its seaward face is a series of berms. The fore-slope is 3:1. "The shingle-levee," says Beaumont, "when viewed as an isolated phenomenon, merits but little attention, but in its relations to other phenomena we recognize that it has a great influence upon a crowd of important facts." I think, as a rule, the shingle-levee, as such, cannot be traced below ordinary high water, so that it is decidedly a *storm-record*. With no desire to involve myself in the discussion of wave theories, I must state one point, because of its bearing upon my general subject. The positive and negative, or *crown* and *hollow* portions of a storm wave, are of unequal height, so that the rise above the sea-level (plane of equal volumes) is considerably greater than the fall below. Many shoals, whose depths given upon our charts are less than half the range of ordinary storm-waves, have never been seen exposed in the trough of the sea. Some years since a heavily laden ship, drawing about eighteen feet of water, was driven by an easterly gale across several of the Nantucket shoals, upon which, according to our maps, the depths scarcely exceed eleven feet. She struck heavily many times, but the leadsman never called less water than the chart indicated. Standing upon the beach during a heavy storm, one rarely sees, as the waves retire, much more of the strand than in ordinary weather; and Robinson Crusoe's thrilling account of his race for life across the floor of the ocean, during the recoil of the sea, disturbs our confidence in him at the outset of his narrative.

The dikes along the coasts of Europe may be said to furnish limiting measures of the heights of overflows not wholly local in their significance. Until a comparatively late period, the sea-dikes in Holstein and Schleswig were raised but ten feet, and in Holland but ten to thirteen feet above ordinary high-water mark. Modern engineers, however, have carried these works to greater elevations. On the Schleswig coast, eighteen and a half feet above the highest spring tides is regarded as entirely safe.† On the Dutch coast, after a recorded experience of four hundred years, the grand dike of Petten has been carried up to twenty-one feet above ordinary high water,‡ and upon the Mediterranean shore of France sixteen and a half feet is proposed for new works.§ As the injury suffered by sea-dikes has been principally due to the rush of water down the landward slopes during overflows, it has been deemed prudent to raise the crest of the most exposed and important works to the extraordinary heights I have stated.||

* Reported by myself in 1867.

† Testimony of Captain Carstenson, dike inspector, cited by J. Paton, M. Inst. C. E.

‡ From a diagram entitled "Scituate der Pettimer Zeeweering," furnished me by J. F. W. Conrad, engineer of the Waterstaat.

§ Ponts et Chaussées, Department de l'Herault, report of the engineer-in-chief.

|| The highest dike that I call to mind is that of West Capelle, over twenty-six feet above the tide.

Breakwaters do not furnish what I have termed "limiting measures," because many of them have been built with the expectation that storm-seas would leap over them, while others have been carried high for the sake of *weight*. Although most of the breakwaters have been built in situations already partially sheltered, there are instances where they have been more exposed than the adjacent coasts.

PROFESSOR PEIRCE'S CRITERION.

This is a rule for deciding upon the propriety of attempting to reclaim the marshes of a tidal river by the construction of a transverse sluice-dam. It was offered expressly for a guide in the cases before the Massachusetts Board of Harbor Commissioners, and finds its place properly in this portion of my report.

"*Draw a tangent to the tidal curve at the point where the tidal current changes from ebb to flood; if this tangent intersects the descending branch, the reclamation will preserve from overflow all the land which is higher than the point of intersection.*"

In explanation of the above, it is simply necessary to state that the river supply is regarded as uniform, and therefore to be represented upon the diagram as a straight line, which will, of course, be the prolongation of that which represents the rise at the moment of *slack-water*, when the outflow and inflow are in equilibrio. If, as is usually the case at the mouth of a river, the observed curve is nearly that of the sines for a circle whose radius is half the range of the tide, reclamation is possible if the flood-current begins to run up *within* one hour and forty-three minutes after the time of low water. If slack-water occurs at the instant of low water stand, drainage of the marsh to a depth equal to the range of the tide is practicable; but if the flood-current does not commence to run up until one hour forty-three minutes after low water, the fresh-water accumulation, while the sluice-gates are closed, will equal the range of the tide. Fig. 2, of Plate No. 27, illustrates these two cases.

Care must be exercised in the application of this rule in certain cases: 1st. When the stream has a transverse bar rising above the plane of low water, the observations used must be those made upon the bar itself. In the instance where a "submersible" dam exists, the rising curve *within* the obstruction resembles that observed outside, except that the lower portion to the height of the dam is cut off. If, for instance, the dam is elevated to the height of half tide, no tangent to the tidal curve within will intersect the descending branch, and yet the case may be one of possible drainage to an adequate depth. In Fig. 3, I offer curves plotted from simultaneous observations near Hyannis, Massachussetts, in which the larger tide is that of the harbor, and the smaller that of Dunbar's Salt Pond, which is separated from the harbor by a natural bar, considerably elevated above the plane of low water outside, although never dry. No fresh-water feeders exist, and drainage to the level of the bar is of course possible, although the criterion (misapplied to these curves) would say not. 2d. This rule is inapplicable, I think, to an inlet communicating with a great lagoon, because in this case, even in the entire absence of fresh-water feeders, the current epochs will be late.

PART II.—FIELD-WORK.

At the request of the Massachusetts Board of Harbor Commissioners, you instructed me to examine the marshes and shores of Scituate and Marshfield, to determine the practicability of reclaiming the tide-lands, and to ascertain the probable effects of reclamation upon the navigable facilities of North and Green Harbor Rivers. In these studies I have pursued my usual custom of including in my examinations all the features of the coast which properly belong to a physical survey, so as to make this work a part of our general scheme of a physical history of the seaboard.

GREEN HARBOR RIVER.

This *river*, so called, is the drain of about fifteen hundred acres of marshes, situated mostly in the township of Marshfield. It receives two considerable tributaries and innumerable brooks and creeks in its meandering course. The lower reach of the river is known as Green Harbor, whose length from Turkey Point to the bar is about seven-eighths of a mile, and whose maximum low-water width scarcely exceeds five hundred feet. A sand-bar obstructs the entrance, upon which there is

from two to three feet of water at ordinary low tide. The average rise is nine feet, and vessels can take the ground within the harbor at low tide without injury. The shelter from winds and sea is good. As far as I could learn the trade of the place employs but one small vessel, but during the summer, many small yachts, for the accommodation of watering people, make here a rendezvous. It is not entitled to the slightest consideration as a port of refuge, although vessels have been known to run into it under desperate circumstances.

It has been proposed to reclaim the marshes by constructing a transverse sluice-dam at the head of the harbor, and I visited the scene during the month of June, with the two-fold object of determining the practicability of this reclamation, and the likelihood of resulting injury to the entrance. The problem of reclamation presented is one of the simplest kind, and I was enabled to reach a positive result from a few experiments and a very limited survey; but the question of injury to the entrance has perplexed me very much. I shall offer, however, an argument upon this point.

The place chosen for gauging the river was near Turkey Point, where the uplands approach the stream on either hand, and where a dam could be most economically and effectively constructed The table which follows furnishes the elements for a profile of the section from upland to upland, crossing the river at the place of gauging. (See Fig. 4.)

The tide was observed for thirteen hours upon the 30th of June. The range was 8.90 feet, which is about what I should compute for Cape Cod Bay at the same age of the moon, and no unusual distortion of the profile could be detected. The marshes are at the level of high water in this portion of the basin, and supposing, at the date of our observations, gates to have been closed upon the river at the time of low water, the accumulation behind them during the following six hours would have been, according to your criterion, about three feet, so that the surface of the marsh would have been six feet above the water-table at time of high water in the bay. This depth of three feet is largely in excess of the fresh-water supply, because many of the creeks do not fully discharge their tide-waters during the fall in the main river. Our hydrometer, at low water, gave a density of 1.0195, indicating that the out-flow was then three-quarters sea-water. Indeed, the current observations show that the fresh-water discharge was exceedingly small, and that gates of ordinary dimensions may be relied upon for draining this basin perfectly in summer.

The river, at its embouchure, flows into the sea in a course but little to the eastward of south, with rocks upon its left and sands upon its right bank. These sands, driven by the waves and the flood-current, are constantly invading the river's mouth, but are driven back by the out-flow, and the bar is for the most part formed of material from outside, which is left in the debatable district between the opposing forces. I think that it is only during heavy weather that the flood-current, aided by the waves, can overbalance the scour of the ebb, even during dry seasons, when the fresh-water outflow is itself too small to be considered, and I base my opinion upon the following considerations: The shifting material is sand, and this is not suspended, but rolled or driven along upon the bottom at a rate far less than that of the water itself, so that the progress that it ultimately makes, and the direction it takes, must be determined by the power and direction of the resultant of the forces, precisely as if these forces acted simultaneously. Now, although the flood and ebb, at low-river seasons, are essentially the same as regards volume, they are quite unlike as regards velocity, *i. e.*, working-power. The veins and arteries of the marshes are filled late and drained late as regards the tidal time at the mouth of the river, so that the greatest in-flow is called for when the water is high upon the bar, while the greatest out-flow is so much behindhand as to reach the bar when the latter has but a small section; the former, therefore, creates but little horizontal motion, while the latter creates a rapid current. When we consider that the *work* of a stream increases with the square of its velocity, we should not be surprised to find the ebb at the mouth of a river playing the dominant part in the excavation of channels. For instance, when the tide at our station had risen two feet, or less than one-fifth of its range, the velocity of in-flow was 0.50 feet per second, but when it had fallen to the same stage, the outflow was 1.40 feet; in other words, the working-power in the same section was *eight times as great upon the ebb as it was upon the flood.* If a sluice-dam were to be constructed, shutting out the tides from the marshes, the fresh-water out-flow only would be left to resist the action of the waves, and, as far as I can judge, the summer discharge would be impotent. In the introduction to this report I have pointed out instances of

little harbors that have been injured by weirs and dams like that proposed for Green Harbor River, and I have little doubt that a decline in the depth on the bar will follow the reclamation of the marshes. It is true that the direction of the embouchure is favorable as regards shelter from the sea, and that the supply of material is not so great as at many other points along shore, but I have about made up my mind that in course of time, after the dam is constructed, the inlet will become a "tide-harbor," like Scusset and Sandwich, *i. e.*, dry at low tide, at least upon its bar.

Section of river at Turkey Point, (Fig. 4.)

Distance in feet.	Height above low water of June 30, in feet.	Remarks.	Distance in feet.	Height above low water of June 30, in feet.	Remarks.
0	13.46	Upland, left bank.	835	9.34	On island.
36	12.29		838	9.17	On left bank of main stream.
59	10.00	Edge of upland.	856	1.60	River bed.
131	9.61	Marsh, salt grass.	858	0.20	Do.
196.8	9.33		868	−4.2	Do.
262.4	9.01	(Plane of high water = 8.90.)	878	−5.8	Do.
318	8.63		888	−4.9	Do.
393.6	8.74		898	−6.0	Do.
459.2	8.99		908	−6.2	Do.
524.8	8.62		918	−6.3	Do.
557.6	8.99		928	−6.9	Do.
590.4	8.47	Left bank of stream.	938	−6.2	Do.
600	2.4	River-bed.	948	−6.1	Do.
610	1.4	Do.	958	−5.4	Do.
620	0.6	(Plane of low water = 0.00.)	968	−5.0	Do.
630	−0.3	Do.	978	−2.1	Do.
640	−0.3	Do.	988	−2.2	Do.
650	−1.0	Do.	998	−2.2	Do.
660	−1.1	Do.	1,008	−1.2	Do.
670	−1.1	Do.	1,018	−0.4	Do.
680	−1.1	Do.	1,028	0.2	Do.
690	−1.1	Do.	1,038	0.8	Do.
700	−1.2	Do.	1,045	1.6	Do.
710	−1.2	Do.	1,088	4.05	Right bank of main stream.
720	+0.7	Do.	1,137.4	8.61	Marsh.
730	8.59	Right bank of stream.	1,186.6	9.45	
772.6	8.88	On island.	1,207.2	10.40	
798.6	8.65	Do.	1,269	11.11	Turkey Point, bushes.

NORTH RIVER.

Dean's History of Scituate, published in 1831, furnishes a brief description of the North River, which I shall quote, not only because as a general sketch it is still sufficient, but also because it comments upon the facilities for ship-building and navigation which the river afforded before the recent disastrous inroads of the sea:

"This stream received its name before 1633, and probably from the circumstance that its general course is from south to north, or that it was farther north from Plymouth than South River in Marshfield, which meets the North River at its mouth. The North River is a very winding stream, flowing through extensive marshes, sometimes, as it were, sporting in the broad meadows in the most fanciful meanders, and sometimes shooting away to the highlands which border the meadows. There is one reach which has long been called the 'No Gains,' from the circumstance that, after flowing from side to side, and almost turning backward for several times, it has, in fact, flowed several miles and gained but a few rods in its direct progress to the sea. From the sea to the North River bridge, on the Plymouth road, an air-line would not exceed seven miles, while the line of the river amounts to eighteen miles. The tide rises at the North River bridge from three to five feet, and there is a perceptible tide two miles higher up. It has three chief sources, the Namatakeese and Indian Head, which flows from the Matakeeset Ponds in Pembroke, and the Drinkwater, which has its sources chiefly in Abington. The tributaries are the three Herring brooks on the Scituate side, and the Two-Mile Brook and the Rogers' Brook on the Marshfield side." * * * * "Just

below, and at an air-line distance of a little more than three miles from North River bridge, is Union bridge. A half mile lower, on the Scituate side, is King's Landing, and about half a mile on the same side is Hobart's Landing. Here, we believe, the first vessels were built, by Samuel House, as early as 1650." * * * * "Here the ship Columbia (Captain Kendrick) was built by James Briggs, A. D. 1773. It was the first ship that visited the northwest coast from this country. Captain Kendrick explored the river Oregon, and named it from the name of his ship, which name will probably prevail henceforth. At the distance of another half mile below is Little's bridge, at which point we believe vessels have been built on the Marshfield side. The meadows above this station are of very various width, in few places exceeding a mile; but below there is a wide expanse of marsh, anciently called the 'New Harbor Marshes.' The scenery here is on a sublime scale when viewed from Coleman's Hills, or from the Fourth Cliff. The broad marshes are surrounded by a distant theater of hills, and the river expands and embraces many islands in its bosom. Here it approaches the sea, as if to burst through the beach, but turns almost at right angles to the east, and runs parallel with the sea-shore for nearly three miles before it finds its outlet, leaving a beach next the sea for nearly twenty rods in width, composed principally of round and polished pebbles, excepting only the Fourth Cliff, a half mile in length, which comprises many acres of excellent arable land. Nearly a mile above the river's mouth is White's Ferry, where is a wharf and a small village on the Marshfield side. Here vessels have been built, and many that have been built above here receive their rigging. The river's width may be estimated as follows: In ordinary tides, at Union bridge, seven rods; at Little's bridge, nine rods; it expands below to a half a mile in width, where it is now called Fourth Cliff Bay, and formerly New Harbor; here the channel divides, and unites again a mile below; a half a mile above its mouth it is fourteen rods in width. The channel at its mouth often shifts its place, owing to the nature of the sandy bottom and to the violence of the stream and the tides. It seldom affords more than nine feet of water, even when there is but one channel; but it often happens that there are two channels when the water is something less. This fact accounts for the difficulty and expense of carrying out the vessels built upon this river; and yet only in part, for there are shoals above over which vessels of two hundred tons and upward must be lifted with gondolas or heaved with kedges. The principal are Wills' Shoal, at the upper part of the New Harbor Marshes, and the Horseshoe Shoal."

Since the above statement was written forty years have elapsed, during which important physical changes have occurred, which, in connection with other circumstances, have led to the abandonment of nearly all commercial enterprises upon the North River; and the project now entertained for reclaiming the marshes, by sluicing out the tide, involves the sacrifice of no important interests of navigation.

The injuries which the channel-way has suffered have been principally due to the waves, which, during violent storms, have burst through the narrow strip of beach that separates the lower reach of the river from the ocean. Appreciating the importance of this natural dike in connection with the projected reclamation, I devoted some time to its inspection, with a view to pointing out its weak places. With the exception of Fourth Cliff, which appears to be the smaller portion of a high hill, once extending into the sea, the entire beach is but a windrow of sand and stones cast up by the waves and subsequently modified in part by the winds, differing only in matters of detail from the *littoral cordon* of our Southern States.

Shingle-levees.—A portion of this beach is permanent, the forces which created it having, as it would seem, ultimated their effects. I refer here to the shingle-levee, which, from the point where the stream "*approaches the sea as if to break through,*" extends like a strong bulwark half way to the river's mouth, interrupted only by Fourth Cliff, from whose waste a portion of the material of the levee seems to have been selected.

It is not impossible that the river once found its outlet between the Third and Fourth Cliffs, as most of the people living in the neighborhood conceive. Instances are numerous where streams have been turned aside, and sometimes cut off from the sea, by the advance of shingle.

Shingle-levees appear to me to be worthy of careful study, because they are the best natural measures of the power of storm-waves, and I have made the dimensions of this one at Scituate a special subject, in order to ascertain to what height the *dikes,* required farther down the beach, must be carried in order to prevent the overflows that now frequently occur.

The portion of the levee which lies between Third and Fourth Cliffs is about four thousand three hundred feet in length, with a general elevation of sixteen feet above the plane of high water, and a base of two hundred feet. It is composed of round and oval stones, those near the water-line of the seaward side being the largest, and those upon the summit the most flattened. Paving-stones are gathered from the lower portions of the outside, but upon the summit the average size may be stated at three and a half inches maximum diameter, and one inch thick in the middle.

The crest of the levee appears to the eye perfectly horizontal, and but slightly curved back from a straight line. The table of levelings given below, however, shows that there are depressions at either extremity, and that it is only the highest portion that is very near the horizontal for any considerable distance.

Longitudinal section of shingle-levee.

Datum = High water of the sea.

Distance in meters.	Height above mean high water of sea.	Distance in meters.	Height above mean high water of sea.	Distance in meters.	Height above mean high water of sea.
0	14. 32*	5. 40	16. 15	10. 20	13. 71
60	12. 83	6. 00	16. 15	10. 80	13. 04
1. 20	15. 45	6. 60	15. 65	11. 40	13. 41
1. 80	17. 00	7. 20	15. 30	12. 00	12. 71
2. 40	16. 40	7. 80	14. 73	12. 60	11. 01
3. 00	16. 70	8. 40	15. 03	13. 20	9. 21†
3. 60	16. 77	9. 00	14. 29	13. 20	13. 21‡
4. 20	17. 10	9. 60	13. 71	13. 40	22. 41§
4. 80	15. 95				

* Foot of Fourth Cliff. † On levee. ‡ On bluff. § On Third Cliff.

Within the memory of persons now living in Scituate, the sea has once (during the Minot's gale) leaped over this levee, and the sea-water had several times been seen oozing through, but to no extent that could be injurious in ordinary winter storms.

The height of this levee is greater than is usual among such formations, and its stones are larger. The maximum height given in our table is seventeen feet above mean high water of the sea. Redman estimates the ordinary height of these formations in Great Britain at six to ten feet.

The two slopes of our levee, as given by our cross-sections, are very unlike in some respects; that toward the sea presents a series of berms, miniatures of the great levee, thrown up by subsequent storms,* while the leeward slope (toward the river) is a smooth hollow curve. (Figs. 5, 6, and 7.)

In the following tables I give the elements for profiles of ten cross-sections of our shingle-levee, and a mean section from the higher and less disturbed portion. (See Figs. 5, 6, 7, and 8.)

* Redman and Coode, in their papers read before the Institute Civil Engineers, used the word "fulls" for these windrows or berms which mark the action of the recent storms.

Sections of shingle-levee.

	Section I.		Section II.		Section III.	
	120 meters.		240 meters.		360 meters.	
	Distance in feet.	Height above mean high water of sea, in feet.	Distance in feet.	Height above mean high water of sea, in feet.	Distance in feet.	Height above mean high water of sea, in feet.
Fore shore	65.6	0.13	....	....	78.7	0.21
	59.0	2.33	....	....	62.3	4.51
	52.5	4.63	....	....	52.5	6.41
	45.9	4.93	65.6	1.60	45.9	7.31
	39.4	6.03	52.5	5.20	39.4	9.11
	32.8	6.43	36.0	7.80	29.5	10.17
	19.7	9.05	29.5	9.50	22.9	13.27
	9.8	13.45	19.7	8.83	16.4	15.17
	6.6	14.15	6.6	13.80	6.6	15.57
Crest	0	15.45	0	16.40	0	16.77
Back shore	6.6	14.95	13.1	14.20	3.3	16.47
	19.7	12.85	26.2	9.60	16.4	13.87
	32.8	9.82	39.4	6.12	26.2	10.04
	45.9	7.72	65.6	2.80	36.0	6.70
	65.6	6.42	82.0	1.40	59.0	3.90
	98.4	4.52	98.4	0.70	68.9	4.00
	131.2	2.72	111.5	—1.30	85.3	3.00
	144.3	1.92	....	....	104.9	2.30
	154.2	1.12	....	....	118.0	—0.10
	164.0	—1.28	....	....	134.5	—1.42

NOTE.—The datum plane is mean high water of the sea. The distances in meters are measured along the crest from Fourth Cliff.

Sections of shingle-levee.

	Section IV.		Section V.		Section VI.	
	480 meters.		600 meters.		720 meters.	
	Distance in feet.	Height above mean high water of sea, in feet.	Distance in feet.	Height above mean high water of sea, in feet.	Distance in feet.	Height above mean high water of sea, in feet.
Fore shore	88.6	—1.56	....	....	....	....
	72.2	1.14	98.4	—2.50	....	....
	62.3	3.14	75.4	0.20	88.6	—2.80
	55.8	4.84	65.6	2.50	55.8	2.90
	39.4	7.04	55.8	5.10	49.2	4.50
	32.8	8.74	49.2	5.10	32.8	7.30
	29.5	9.82	36.0	7.40	22.9	8.00
	22.9	12.45	29.5	7.90	19.7	9.07
	13.1	12.85	19.7	9.38	9.8	10.90
	6.6	13.95	9.8	11.90	6.6	12.00
Crest	0	15.95	0	16.15	0	15.30
Back shore	9.8	14.65	9.8	15.65	9.8	14.30
	19.7	12.55	16.4	14.55	26.2	10.60
	42.6	6.63	26.2	11.55	42.6	6.40
	75.4	3.86	32.8	9.12	75.4	2.40
	108.2	2.76	49.2	4.86	108.2	1.50
	141.0	—0.24	65.6	2.66	141.0	0.70
	157.4	—0.74	82.0	1.76	173.8	0.70
	164.0	—0.04	114.8	1.26	....	....
	183.7	—0.14	147.6	0.56	....	....

Sections of shingle-levee.

	Section VII.		Section VIII.		Section IX.		Section X.	
	840 meters.		900 meters.		1,080 meters.		1,200 meters.	
	Distance in feet.	Height above mean high water of sea, in feet.	Distance in feet.	Height above mean high water of sea, in feet.	Distance in feet.	Height above mean high water of sea, in feet.	Distance in feet.	Height above mean high water of sea, in feet.
	....	....	....	....	....	....	114. 8	—5. 00
	....	....	....	....	....	....	88. 6	—2. 00
	98. 4	—3. 00	....	....	124. 6	—4. 56	65. 6	1. 20
	82. 0	—1. 10	....	....	108. 2	—3. 66	59. 0	2. 90
	65. 6	2. 40	12. 14	—4. 50	75. 4	—0. 16	55. 8	4. 10
	59. 0	4. 83	88. 6	—1. 20	68. 9	1. 24	49. 2	4. 40
	49. 2	5. 00	68. 9	1. 20	55. 8	4. 72	42. 6	5. 40
	42. 6	6. 70	55. 8	4. 50	39. 4	6. 14	39. 4	6. 70
	32. 8	6. 91	42. 6	6. 40	22. 9	7. 14	26. 2	7. 01
	22. 9	8. 80	29. 5	6. 64	13. 1	10. 34	16. 4	8. 50
	9. 8	11. 60	6. 6	12. 20	9. 8	10. 94	6. 6	10. 70
Crest	0	15. 03	0.	13. 71	0	13. 04	0	12. 71
	6. 6	13. 70	9. 8	13. 30	6. 6	12. 80	6. 6	12. 30
	16. 4	11. 10	29. 5	9. 60	16. 4	11. 40	16. 4	11. 20
	32. 8	8. 11	42. 6	7. 50	29. 5	9. 11	49. 2	7. 40
	49. 2	5. 00	75. 4	4. 87	55. 8	5. 74	82. 0	2. 88
	72. 1	2. 30	108. 2	2. 90	72. 2	3. 94	114. 8	1. 20
	98. 4	1. 70	141. 0	1. 00	104. 9	2. 04	147. 6	0. 50
	127. 9	0. 60	173. 8	0. 70	121. 4	1. 64	180. 4	—0. 70
	164. 0	0. 60	....	....	154. 2	1. 34	....	....
	....	....	....	....	186. 9	0. 44	....	....

Mean of Sections I, II, III, IV, V, VI. (Fig. 8.)

	Distance.	Height above mean high water of sea, in feet.	Slope.
Fore shore........	90 feet........	—1. 82	0. 133
	80 feet........	—0. 49	0. 199
	70 feet........	1. 50	0. 107
	60 feet........	2. 57	0. 279
	50 feet........	5. 36	0. 162
	40 feet........	6. 98	0. 163
	30 feet........	8. 61	0. 187
	20 feet........	10. 48	0. 243
	10 feet........	12. 91	0. 309
Crest........	0 feet........	16. 00	0. 000
Back shore........	10 feet........	14. 84	0. 116
	20 feet........	12. 50	0. 234
	30 feet........	9. 50	0. 292
	40 feet........	7. 12	0. 246
	50 feet........	5. 60	0. 152
	60 feet........	4. 52	0. 108
	70 feet........	3. 72	0. 080
	80 feet........	3. 06	0. 066
	90 feet........	2. 66	0. 040
	100 feet........	2. 27	0. 039
	110 feet........	1. 60	0. 067
	120 feet........	1. 44	0. 016
	130 feet........	0. 89	0. 055
	140 feet........	0. 87	0. 002
	150 feet........	0. 54	0. 033
	160 feet........	0. 01	0. 053

For the height of the above mean section Caland's dike formula would give a fore slope of 4 : 1; but, as the table shows, the inclination varies from a maximum of 3 : 1 to a mean of 5 : 1 for our natural dike. In the grand dike of Petten, (North Holland,) which is still in course of construction, the mean slope is 9 : 1; but I find from my notes made upon the spot in 1868 that for the storm-belt, covered with basalt blocks, the slopes are 5 : 1 and 3 : 1; so that the work of several centuries begins to approach the economy of nature.

The leeward slope of our levee, for different sections, is very nearly the same from point to point except near the base, where it is affected by different elevations of the river-bed upon which it lies. It is probably the curve of least resistance for the material employed. It sometimes approximates quite closely the cycloid, and it always has an aproning to protect the base. If it were steeper, the fall of overflowing water would excavate the marsh at the foot and endanger the whole structure; if it were less inclined, there would not only be a waste of material, but, in the event of a rapid succession of overleaping seas, the accumulated waters might react and burst through the crest.

My assistant, Mr. H. L. Marindin, has recently examined the levee near Chelsea, Massachusetts, the southern portion of which is more exposed to the sea, and therefore the highest, reaching an extreme elevation of 14.13 feet above mean high water. The fore slope of this portion has an average inclination of 5 : 1, and an extreme near the crest of 2¾ : 1. The exposure is only to the south-easterly quadrant, and the shallow flats, which extend a long way to the seaward, break the force of the sea. The longitudinal profile of this levee shows a decline of height as the observer moves to the northward, reducing the angle of exposure, and falling under the shelter of Nahant. This levee has a rear slope of 3 : 1 above the apron.

Below Fourth Cliff the shingle-levee continues for a considerable distance, but gradually loses its distinctive character, and merges with the sands, which seem to have preceded all other material in the march southward. In the year 1855 the communities about the North River attempted to cut a new outlet in this portion of the beach, using at first hand-labor, but ultimately employing a dredging-machine. The bottom was removed to a depth of six feet below the marsh level, but not to the low water of the sea. Contrary to expectation, the water, instead of flowing seaward, rushed in toward the river, Fourth Cliff Bay being at times, as we find from our observations, below the high water of the sea. The influx was very strong, but seemed quite powerless to enlarge or deepen the trench through the firm and unctuous soil of the marsh; to use the expression of the workmen, "*the stream wouldn't gull.*" Heavy weather came on soon after the work of the dredging-machine ceased, and the waves drove in masses of sand and stones, which soon choked up the pass. In course of time a shingle-levee formed across the inlet, and rose to the height of 10 feet above the high-water plane of the sea. I give a section of this new formation, in which no decided berms appear.

Cross-section of new levee.

FORE SLOPE.		REAR SLOPE.	
Distance from crest, in feet.	Elevation above mean high water of sea, in feet.	Distance from crest, in feet.	Elevation above mean high water of sea, in feet.
137	— 7.6	0	10.9
102	— 4.6*	20	7.3
72	— 1.8	33	5.3
49	1.5	59	3.5
39	4.0	125	1.8
33	5.2	192	— 0.3
23	6.9	256	— 1.7‡
13	10.5	....	....
6	10.7	....	....

* Half tide or mean lever of sea. † Crest. ‡ High-water plane of river.

NOTE.—The average fore slope, above the plane of high water, is 5 : 1, while the greatest inclination, (near the crest,) is 2¾ : 1.

I glean one very curious fact from those employed in opening this channel, viz, the original bank of shingle was found to extend downward only to the surface of the marsh, which was not sensibly depressed beneath its weight. I infer that, as Fourth Cliff wears away, the whole beach falls back, and the present banks of sand and shingle are really superimposed upon ancient meadow lands or river channels. The marshes are not floating bogs like the *koogs* of Denmark, or liable to slump down after inclosure, like the *polders* of Holland. The newly formed levee, across the mouth of the artificial outlet, exerts a pressure of over twelve hundred pounds to the square foot upon the marsh beneath its crest, and the weight of the original bank, as far as I can judge, was over seventeen hundred pounds to the square foot under the crest. I have allowed in these estimates 25 per cent. for voids. Old rubble breakwaters that have been shaken down by the waves to a state of repose occupy still a space 25 to 30 per cent. greater than the rock *in situ*.

Some shrinkage will no doubt take place after drainage is effected, but this will not, I think, exceed 10 to 12 per cent. If the *water-table* is dropped four feet I shall expect the marsh surface to sink about six inches.

Sand-beach.—Further down the Scituate Beach the stones gradually give place to sand, and the shore no longer reflects the action of the sea alone, but is diversified by dunes blown up by the winds. There are occasional points where traces of overflow appear, and I give the section of one of the slue-ways formed by the Minot's gale, and traversed by the sea at least once a year since that memorable storm:

Section from upland to ocean, crossing North River at Slant Spar, (*Fig.* 10.)

Distance in feet.	Elevation in feet.	Distance in feet.	Elevation in feet.
0	4.34	478	—3.6
36	1.72	493	—2.9
85	0.93	508	—2.9
125	1.44	523	—2.9
141	1.19	538	—2.9
243	0.37	554	—0.92
262	0.72	590	1.08
328	—0.92	656	2.89
343	—2.9	934	5.05
358	—3.0	1,000	5.50
373	—4.5	1,066	6.78
388	—4.9	1,197	8.76*
403	—4.2	1,262	6.68
418	—4.2	1,331	4.94
433	—4.2	1,387	0.95
448	—3.9	1,426	0.71
463	—3.9	1,505	—4.00

NOTE.—Datum = High-water plane of river, June 23, 1870 = 1.70 feet below mean high water of sea.

* = 7.06 above mean high water of sea.

The maximum height of this slue-way is seven feet; this may be regarded as the measure for annual overflow, especially as I find the same measure on other parts of the New England coast.

I have given in Fig. 10 a profile, plotted from the preceding table, because it illustrates so well the double action in overflow, the violent dash against the seaward face, and the flowing down on the opposite slope. On sandy shores, a mound thrown up by the sea can nearly always be distinguished from one due to the wind; in the former the steeper slope is *seawards*, in the latter *leeward*, so that an overflow reverses the order of the slopes found in a dune. Sections which I have since run across the "Haulover," at the head of Nantucket Harbor, and those through the slues of Cotamy Beach, at the head of Edgartown Harbor, give the same general curve with the same maximum elevation *within six inches*. In running water (in the bed of a river for instance) the sands take the form of flat dunes, which correspond in the order of their slopes with those on land.

General rise.—The *mean-level* rises during storms from seaward, and this must always be taken into account in projects for dikes and dams. This *general rise* can best be measured by observing the height of the water's surface in sheltered coves and harbors. Major Graham's report on Cape Cod Harbor shows, from tidal observations between 1833 and 1835, that a twenty-four hours' gale from the southeast (*i. e.*, directly into Massachusetts Bay) causes a general rise of 3.33 feet. The coping of the United States dry-dock at Charlestown was designed to be above the highest tide, and was placed 4.69 feet above mean high water. The sea has actually risen 0.4 above the top of this coping once during the past twenty years. If we grant that the storm-rise is affected by the configuration of a harbor or bay in no greater degree than the ordinary tide, we must apply a correction to the dry-dock rise of nearly 10 per cent. in order to reduce it to its proper proportion for the outside coast. We have then four and a half feet for the *general rise* during violent storms. I do not think it necessary to go back more than twenty years in estimating the height to which the sea is likely to rise, because there is no economy in providing for contingencies which do not present themselves more than once in a life-time. In Holland, where the lives of thousands depend upon the security of the dikes, the works are only provided for ten feet general rise, although the tradition of the Cimbrian flood is over forty, and the Deluge greater yet.

Dean's History mentions that the sea has been known to flow over the isthmus which divides Scituate Harbor from the North River, and I am informed that during the Minot's gale the rush over this place was so great as to sweep away fences, &c. I have not time to run a line of levels over this isthmus, which I regret, because I think it would have given an exeellent measure for "*general rise.*" The overflow in the Minot's gale, to which I have just referred, injured the lands to such an extent that it was not until the third season after that the English grass recovered its former luxuriance.

To recapitulate: The heights to which the sea has run upon the outside shore above mean high water of the sea are—

In the heaviest gale observed, (Minot's)	17 feet.
In the heaviest gale of the year	13 "
In ordinary winter storms	7 "

The beach should be protected against a fourteen feet run of the sea. We have found between the Fourth Cliff and the South River junction only five slues which fall below this standard height, and these we have sectioned. The point of the beach near the North River is generally low for twelve hundred feet, but will afford, I think, no source of trouble for many years.

The interior dams must be at least three and a half feet, but need not (if perfectly sheltered) exceed four and a half feet above the mean high-water plane of the sea to escape overflow from the "*general rise*" during storms. The bench of our survey is situated on the right bank of the river, nearly opposite Slanting Spar. It is within a circle cut upon the highest point of a boulder, which boulder may be distinguished from other rocks by its having an iron ring-bolt on one side. This bench is 1.23 feet above *mean high water of the sea*, (as computed.)

Mouth of river.—During the last century the river mouth has been forced to the southward by the advance of the beach a distance of nearly one mile, and, since our survey of 1858, about one thousand feet. A beach of small shingle now stretches from the coast south of the embouchure, and overlaps the beach of which I have been speaking, so that the river makes a sharp turn just before issuing upon the sea.

Between the mouth of the river and White's Ferry the stream has been injured by overflows from the sea, which have not only rendered the channel more shallow but made it narrower than formerly, the material of the beach being much of it too heavy for the ebb-current to remove, and the opposite bank of the stream too firm to yield in due proportion.

The shoalest place in the river is in the vicinity of the slue-way of which we have given the section in Fig. 10. It is encumbered with banks, and the average depth of a pathway one hundred feet wide, along the line of greatest depression, is only five feet in ordinary high water. Tradition says that nearly a century ago the mouth of the river was at this point, and that since tne river moved on there have remained here impediments to navigation. However this may be, the Minot's gale reopened a track over the beach, and poured into the stream a mass of gravel

and shingle that completed the ruin of the river as far as navigation is concerned. We have made a close survey of this portion of the stream, and deposited a chart of it at the office, bearing the names of the observers.

Tides.—Dean's History, as we have seen, gives "three to five feet" as the rise and fall of the tide at North River Bridge forty years ago, and I am inclined to accept the statement, not only because the author is reputed to be careful in such matters, but also because the recollections of Captain Tolman and other persons in this very intelligent neighborhood confirm it. In the present obstructed condition of the rivers, the range of tide at North River Bridge varies from 0.8 to 1.5 feet, and the range does not now exceed these figures at any point above White's Ferry, near which the modern overflows have occurred. The obstructions act as weirs, over which only the upper portion of the tide flows. The highest place in the river bed along the thread of the channel is 1.60 feet below the mean level of the sea, and upon this weir the tide does not rise to the high-water level of the ocean, because of the rush into the reservoir beyond, which does not get filled in the short time allowed.

The following table exhibits the times and heights of a low neap tide:

Tides of North River.

Station.	High water, interval after moon's transit.		Range of tide in feet.
	h.	*m.*	
Cape Cod Bay	11	10	*7.7
Station 1st	11	15	4.7
Station 2d	11	30	3.7
Station 3d	11	40	1.7
Roger's Wharf	11	44	0.8
Little's Bridge	13	42	†0.5
Union Bridge	13	59	0.6
North River Bridge	14	30	0.8

* Spring range = 10.58. † Spring range = 1.1.

The obstructions in the lower reach of the river do not protect the marshes from an inundation on the occasion of a great *general rise* outside, because, after the river mounts two or three feet above ordinary high water, its section becomes very ample all the way from the sea. But the obstructions play their part in preventing the prompt relief from inundation, since, with the subsidence of the *general rise* outside, the sections at the obstructions return to their ordinary dimensions and the outlet is choked. What is true of inundations due to "general rise," is also, in a measure, true of every spring tide. The high-water volumes flow easily up the river into the Fourth Cliff Bay, but are so delayed that when they would return to the sea they find that the fall of the tide has left but a contracted section in the lower reach of the stream, and, although this becomes the scene of a torrent during the low stages of the outside tide, the relief is not afforded for several days. It is especially at the season of hay-cutting on these meadows that the prolonged inundations become injurious; and Captain Tolman informs me that an increase in their durations has been observed and much commented upon by persons whose memories go back to better times.

Of course the order of the tidal currents is very much affected by the tendency of the obstructions to limit the supply of tide-water in the reservoirs during the rise, and pond it back during the fall. The flood current, although it does not begin to run in over the shoals until it lacks but about two hours and a half of high water, continues about one hour and a half after the tide has begun to sink. The ebb current continues about eight hours, and runs most rapidly about the time it is low water in the sea. You will perceive that the flood and ebb, the one pouring in at high water, the other struggling out at low water, cannot be properly compared by their durations alone, but their volumes must be considered since the sections are unlike. Here is a case where "Professor Peirce's criterion" is not applicable for obvious reasons, and it becomes necessary to compute the

fresh water supply from actual gauging. This computation is given in the following table from observations over a short reach just below the shoals:

Mean height of surface.	Time, 23d June, 1870.		Mean section.	Mean velocity, per second, in feet.	Volume, per second, in cubic feet.	Period, in seconds.	Volume, in cubic feet.
	h. m.	h. m.					
0.9	5 34	6 00	705	0.4	282	1,560	439,920*
1.3	6 00	7 00	792	1.6	1,267	3,600	4,561,200†
1.7	7 00	8 00	879	2.6	2,285	3,600	8,226,000
1.6	8 00	9 00	857	1.6	1,371	3,600	4,935,600
1.2	9 00	9 15	770	0.2	154	900	138,600
Inflow							18,301,320
0.9	9 15	10 00	705	0.8	564	2,700	1,522,800
0.6	10 00	11 00	640	2.4	1,536	3,600	5,552,960
0.3	11 00	12 00	575	3.3	1,897	3,600	6,829,200
0.2	12 00	13 00	553	3.3	1,825	3,600	6,570,000
0.1	13 00	14 00	532	3.1	1,649	3,600	5,936,400
0.05	14 00	15 00	522	2.9	1,514	3,600	5,450,400
0.0	15 00	16 00	510	2.9	1,479	3,600	5,324,400
0.10	16 00	17 00	532	2.2	1,170	3,600	4,212,000
0.5	17 00	17 29	618	0.6	371	1,740	645,540
Outflow							42,043,700

* Mean L. W. section 510; mean H. W. section 879. † The height of surface is referred to low water, (4.6 below "Primary Bench.")

Effect of a dam.—From the above table the river discharge may be computed to be 11,871,190 cubic feet during six hours, and this quantity includes any reservation from the preceding higher tides. Now the area of the river surface above the gauging place, and below the North River Dam, is 32,920,470 square feet, exclusive of tributaries and creeks. If, upon the day of gauging, a dam had been thrown across the stream, the average rise of the river behind it would have been 0.36 of a foot in six hours. As the area of the river surface would be reduced by drainage, the average rise, under otherwise similar circumstances, would be slightly augmented.

The figures I have given are true for the period of my observations, but of course vary with the rain-fall at different seasons. My acquaintance with the river is too short to permit me even to conjecture upon what date in the spring the river becomes drainable. On September 29, just before the beginning of the rains, after the long drought of the past season, my aid, Mr. F. H. North, gauged the river again at Little's Bridge, at the head of Fourth Cliff Bay, and found the flood and ebb currents of nearly equal duration, and the density of the water as high as 1.017 on the last of the ebb. In effect the stream had become an arm of the sea, without any perceptible rise due to fresh water.

During the coming winter and spring opportunities will be offered for examining the conditions of the river under the circumstances most opposed to drainage, and I suggest to the marsh owners an occasional repetition of some of the observations I have detailed in this report, that the whole scheme may be reduced to figures, and not a dollar spent that can be saved, or saved at the expense of success.

The removal of the shoals from the lower reach of the river is the obvious remedy for all difficulties of discharge, but the depth to which the dredging should be carried ought not to be decided upon before observations in the wet season are made. Deepening to the level of mean low water of the sea will be the utmost that can become necessary, and I hope that something even may be saved of this.

In addition to the observations which form the basis of the tide table given above, we have half-hourly records of the rise and fall at stations simultaneously occupied, so that we can follow all the tidal phases from the sea to the North River Dam. I am obliged to omit, however, these details,

because they are too voluminous for this report, and would require long explanations, but I shall venture to comment upon them briefly, to show their practical bearing upon the engineer's project.

I conceive that the engineer, in deciding upon the dimensions of his sluice-gates, may find it necessary to compute the variations of the slope, and a study of the progress of the tidal phases will be his best resource.* A gate closed upon a stream produces an effect like that of the rising tide at slack water, and the rise due to the closure is propagated at the same rate (essentially) as that of the tide. In a similar way, the depression caused by the opening of a sluice-gate falls back like the tide. With the North River at the level we found it, the rise on the closure and the fall on the opening of a sluice-gate at White's Ferry would affect Fourth Cliff Bay in about one hour, the neighborhood of Little's Bridge in one hour and fifty-eight minutes, and the neighborhood of North River Dam in two hours and forty-six minutes. The duration of rise or fall would everywhere be equal to the time of closure or opening, so that at North River Bridge the water would sink for two hours and forty-six minutes after the gates were closed, or rise two hours and forty-six minutes after the same were opened. Fourth Cliff Bay performs the function of a reservoir, and the sluice-gates should be placed as short a distance below as other circumstances will admit.

GENERAL CONCLUSIONS RELATIVE TO THE PROJECTS OF RECLAMATION.

First. The marshes of Green Harbor River may be drained by the construction of a sluice-dam at Turkey Point without unusual precautions or expense, but not without injury to the present facilities for navigation below said point.

Second. The North River marshes can be drained by constructing a sluice-dam at White's Ferry, provided the present obstructions below are removed by dredging ; and provided, also, that dikes are carried across the "slue-ways" of the beach, to the height of fourteen feet above mean high water of the sea.

Third. The dams, to escape overflows from the "general rise" during storms, must be carried at least four and a half feet above mean high water of the sea.

Fourth. The marshes after drainage will not sink or shrink more than twelve per cent. of their elevation above the water-table.

SHORES OF NAHANT.

At the request of Professor Agassiz, who became interested in our studies of the littoral cordon, I visited the shingle levees of Nahant, and subsequently directed my assistants to run levels over them. I give in full Mr. Marindin's interesting notes on Pond Beach, &c.:

"As the observer traverses the levee, he finds that the material varies from well rounded shingle to gravel, and further on to angular stones which approach rectangular forms, in the neighborhood of Bayley's Hill, from whose ledges the angular blocks have evidently been broken off.

"At section 1 well-rounded shingles are found, varying from 5 by 4 inches down to pebbles ½ by ½ inch; on this section I have measured the shingle on the fore-shore at every foot of distance from the crest; the measurements show the larger shingle about five feet from the crest and gradually diminishing in size to the water's edge, where it may be called gravel. I have taken for measurement the mean-sized stone at the spaces of every foot from the crest.

"At section 2 the same material is found. Here, however, the levee attains its maximum height, viz, 12.73 feet above mean high water of the sea. From section 2 the material changes, till at section 3 (five hundred feet to the westward of section 1) the size and quantity of shingle has been reduced, and a large mixture of gravel and sand substituted. The largest shingle in this section is found between thirty-five and forty feet from the crest on the fore slope. Here is also seen a line of large boulders, five feet from the crest, which appear to have been placed there by hand, as they are well aligned, forming a low wall parallel to the crest. On this fore-shore I have measured the material also for every foot of distance from the crest; these I give below.

"From section 3 to within forty feet of section 4, the material has the aspect of quarry chips; for a belt of twenty-five feet in front of, and parallel with the crest, the interstices are filled with sand and gravel, and the space below the belt is almost clear gravel to the water line. The rear slope is almost wholly of sand. From the limits just mentioned (five hundred and sixty feet west

*An indispensable computation, if freshets are to be provided for.

of section 1) to section 4 a change occurs, two irregular blocks averaging 4 by 4 by 2 inches on both the fore and rear slopes; a few larger angular blocks are scattered around, mainly along the crest, where they appear to have been laid by hand-labor; one of these blocks measured 2 by 2 by ½ feet cube. The crest of the levee, as far as section 4 and beyond, appears very even, the irregularities being due to the different heights of the blocks composing it. Between sections 4 and 5 the beach, so to speak, ends very abruptly at a point about twenty feet from section 4, and six hundred and twenty feet west of cross-section 1.* Here we find large angular blocks on the fore slope, and smaller blocks about the size and shape of paving-stones on the rear slope; this extends as far as section 5, where the material increases in size both on the fore slope and rear slope to section 6 and to the foot of Bayley's Hill, where the levee ends.

"For a length of two hundred feet from the foot of Bayley's Hill, the profile of the crest of the levee shows a series of pretty uniform depressions and elevations. The direction of these depressions or slues is not normal to the crest, but approaches parallelism with the line of greatest exposure.

"The levee, as near as I could judge, runs in a northerly and southerly direction at this point, while the depressions seem to lie nearly southeast and northwest.

"I have measured two of the largest blocks found on the levee, one on the crest near cross-section 5, at a height of 6.8 feet above mean high water of the sea. From a rough calculation this block contains somewhat over three thousand cubic inches. The other was half way up the fore slope, between sections 4 and 5, about five feet above mean high water; it contains five thousand cubic inches.

"A bench-mark was established on the apex of a boulder inside of the stone-wall in rear of cross-section No. 3. The boulder is conical, and has the letters C. S. cut into it on the side facing the sea. A few small trees are scattered around. This B. M. is 7.467 feet above mean high water of the sea.

"I give in section No. 7 a transverse section of a shingle-mound between Bass Point and Bayley's Hill. This mound was thrown up by the waves between two rocky ledges which extend some distance into the sea; these limit the length of the levee to nearly one hundred and fifty feet. The height increases from either end toward the center, where the measurements of the cross-section give a height of 16.57 feet above mean high water of the sea. The shingle is similar in size and shape to that found at section No. 1 on Pond Beach. No large irregular blocks are seen on this levee, although the adjoining shores are rocky, and ledges extend into the sea at different points."

In a note received as this report goes to press, Professor Agassiz says: "The evidence of the very recent origin of a portion of the shingle-levee at Nahant is as plain and direct as you can wish it; for the larger fragments of rock and smaller materials of which it consists, rest upon a stone-wall built to support a road leading to Bass Point. This wall was not built earlier than 1817. That part of the levee which covers the stone-wall and road leans westwardly upon Bass Point, and eastwardly merges with the levee that extends all along the cove."

---

* The minimum height of the levee is at a point 817 feet west of cross-section 1, 6.47 feet above mean high water; the material is angular blocks.

Sections of levees on Pond Beach, Nahant.

CROSS-SECTION NO. 1.

	Distance.	Height above mean high water of sea.	Slope.	Remarks.
	Feet.	*Feet.*	*Feet.*	
Fore shore.	60	2.77	0.15	Water comes up to this.
	50	4.27	0.17	
	40	5.92	0.10	
	30	6.96	0.30	
	20	9.97	0.70	Well-rounded shingle, varying from 5 by 2 inches down to gravel.
	10	10.61	0.13	
Crest..	0	11.94	0.00	
Back shore.	10	11.02	0.90	
	20	8.92	0.21	
	30	6.44	0.25	
	40	5.14	0.13	Road passes between 40 and 60.
	60	4.00	0.05	
	70	2.86	0.11	
	80	1.55	0.12	
	90	—0.14	0.17	Water surface in pond.

CROSS-SECTION NO. 4—600 FEET WEST OF SECTION 1

	Distance.	Height above mean high water of sea.	Slope.	Remarks.
	Feet.	*Feet.*	*Feet.*	
Fore shore.	60	—1.48	0.09	
	40	0.42	0.15	
	30	1.93	0.10	
	20	2.89	0.25	
	15	4.09	0.25	
	10	5.34	0.36	
	05	7.13	0.07	
Crest..	0	7.52	0.00	
Back shore.	10	6.81	0.07	
	20	6.41	0.04	
	27	5.58	0.12	

CROSS-SECTION NO. 2—200 FEET WEST OF SECTION 1.

	Distance.	Height above mean high water of sea.	Slope.	Remarks.
Fore shore.	63	—0.51	0.19	
	40	3.87	0.12	
	20	6.52	0.25	
	10	9.03	0.37	
Crest..	0	12.73	0.00	Well-rounded shingles, same as at section 1.
Back shore.	10	10.98	0.17	
	20	8.68	0.25	
	30	6.88	0.18	
	40	5.88	0.10	
	50	4.18	0.17	
	60	3.26	0.09	

CROSS-SECTION NO. 5.

	Distance.	Height above mean high water of sea.	Slope.	Remarks.
Fore shore.	50	—1.48	0.12	
	40	—0.33	0.08	
	30	0.46	0.19	
	20	2.41	0.21	
	10	4.53	0.23	Large angular blocks, varying from 4 inches to 2-feet cubes.
Crest..	0	6.83	0.00	
Back shore.	10	6.51	0.03	
	20	6.03	0.05	
	30	5.11	0.10	
	37	3.73	0.20	

CROSS-SECTION NO. 3.

	Distance.	Height above mean high water of sea.	Slope.	Remarks.
Fore shore.	67	0.39	0.27	
	60	2.36	0.12	
	50	3.58	0.19	
	40	5.50	0.01	Fore shore of shingle.
	30	5.65	0.09	
	20	6.60	0.02	
	10	6.81	0.21	
Crest..	0	8.89	0.00	
Back shore.	20	8.70	0.01	
	40	7.95	0.04	Back shore of sand and gravel.
	60	7.12	0.01	
	74	6.85	0.02	

CROSS-SECTION NO. 6—926 FEET WEST.

	Distance.	Height above mean high water of sea.	Slope.	Remarks.
Fore shore.	50	—1.97	0.11	
	40	—0.87	0.26	
	30	1.70	0.27	
	20	4.46	0.27	
	10	7.26	0.28	Large irregular angular blocks, varying in size from 1-foot to 2-feet cubes.
Crest..	0	10.05	0.00	
Back shore.	05	8.11	0.38	
	10	7.23	0.18	
	15	6.73	0.10	
	20	7.03	0.06	
	25	5.93	0.22	
	30	5.03	0.18	

Sections of levees on Pond Beach, Nahant—Continued.

MOUND NEAR BASS POINT, SECTION NO. 7.

	Distance.	Height above mean high water of sea.	Slope.	Remarks.
	Feet.	*Feet.*	*Feet.*	
Fore shore.	65	—1.48	0.19	
	50	1.47	0.39	
	44	3.87	0.14	
	37	4.89	0.71	
	34	6.98	0.31	
	29	8.50	0.33	Well-rounded shingle, varying from 5 by 2 inches down to gravel.
	17	8.87	0.50	
	08	12.11	0.43	
Crest..	0	16.57	0.00	
Back shore.	06	15.56	0.17	
	12	13.81	0.28	
	18	11.86	0.33	
	22	10.79	0.25	

MEAN OF SECTIONS NOS. 1 AND 2.

	Distance.	Height above mean high water of sea.	Slope.	Remarks.
Fore shore.	60	1.13	0.18	Water comes up to this.
	50	2.97	0.19	
	40	4.89	0.12	
	30	6.07	0.22	
	20	8.25	0.16	
	10	9.82	0.25	
Crest..	0	12.33	0.00	
Back shore.	10	11.00	0.13	Well-rounded shingle, varying from 5 by 2 inches down to gravel.
	20	8.80	0.22	
	30	6.66	0.22	
	40	5.51	0.11	
	50	4.37	0.11	
	60	3.63	0.07	
	70	2.86	0.07	
	80	1.55	0.13	
	90	—0.14	0.17	Water surface in pond.

LONGITUDINAL SECTION FROM SECTION 1 TO BAYLEY'S HILL.

	Distance.	Height above mean high water of sea.	Slope.	Remarks.
	Feet.	*Feet.*	*Feet.*	
Along the crest of the levee.	0	11.94	......	Cross-section No. 1.
	100	12.68		
	200	12.73	......	Cross-section No. 2.
	300	12.72	......	Rounded shingle.
	400	12.56		
	500	8.89	......	Cross-section No. 3.
	600	7.52	......	Cross-section No. 4.
	700	7.57		
	800	7.82		
	811	8.32	......	Large angular blocks.
	817	6.47		
	821	7.69		
	837	6.83		
	838	6.83	......	Cross-section No. 5.
	848	8.54		
	857	7.12		
	862	8.17	......	Large angular blocks.
	874	8.72		
	887	7.38		
	896	8.96		
	905	10.00		
	914	8.42		
	926	10.05	.....	Cross-section No. 6.
	934	10.26		
	942	7.97		
	952	10.12		
	966	10.69		
	984	11.09		
	1000	9.59		
	1006	9.69	......	Foot of bluff at Bayley's Hill.
	1012	10.69		

The reader is referred to the *Journal of the Franklin Institute*, Vol. LXII, for a valuable paper on the manner of determining the proper size of sluice-gates, which has been written since my report was completed, by Clemens Herschel, C. E., upon whom the constructive engineering of the proposed reclamations will devolve.

In the prosecution of my physical surveys in this section during the past season, I have been assisted by volunteers from the Massachusetts Institute of Technology. To Mr. Hoyt, (instructor,) and to Messrs. Pike, Stone, Howland, and Curtis, (students,) whose admirable training at the Institute fitted them for immediate usefulness, I am much indebted for the accuracy of my observations, and for the rapidity with which my work was performed.

HENRY MITCHELL,
Chief in Physical Hydrography, U. S. C. S.

Professor BENJAMIN PEIRCE,
Superintendent U. S. C. S.

No. 1.

Fig. 1

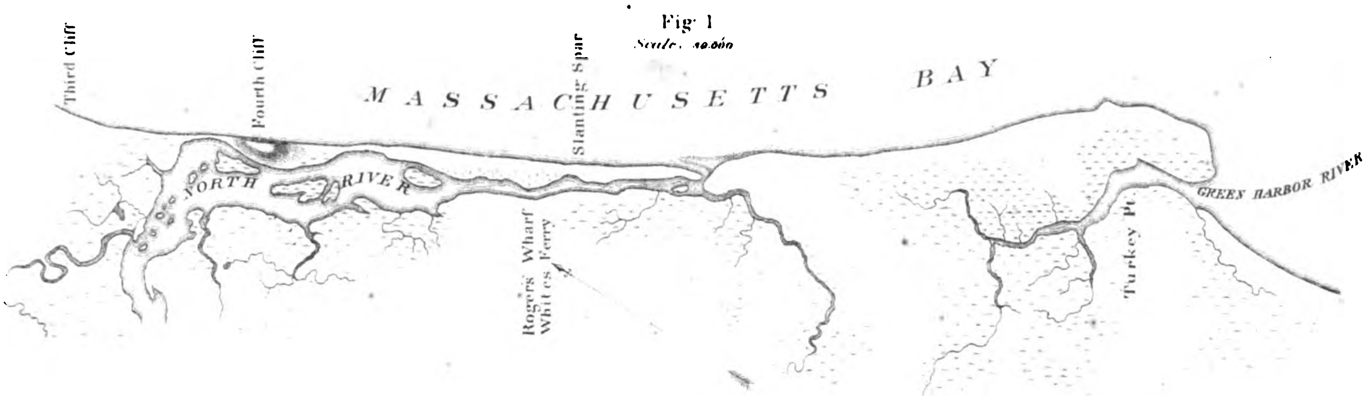


Fig. 2.

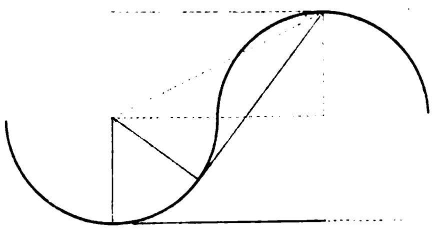
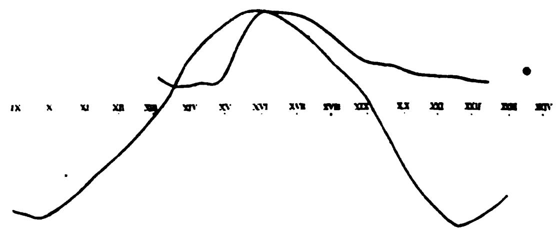
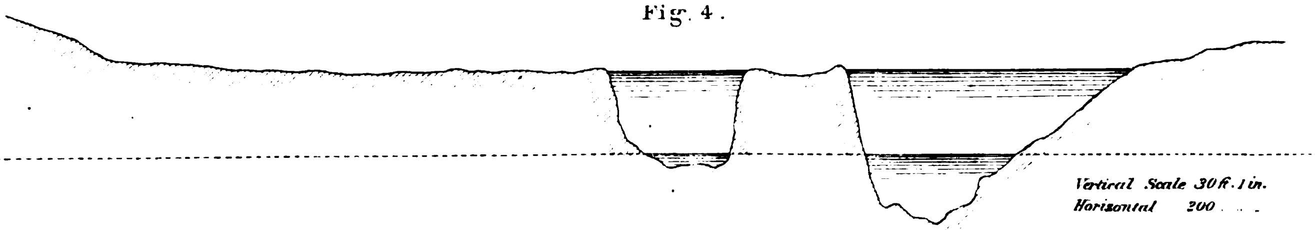


Fig. 3.



SECTION CROSSING GREEN RIVER AT TURKEY POINT, MASS.

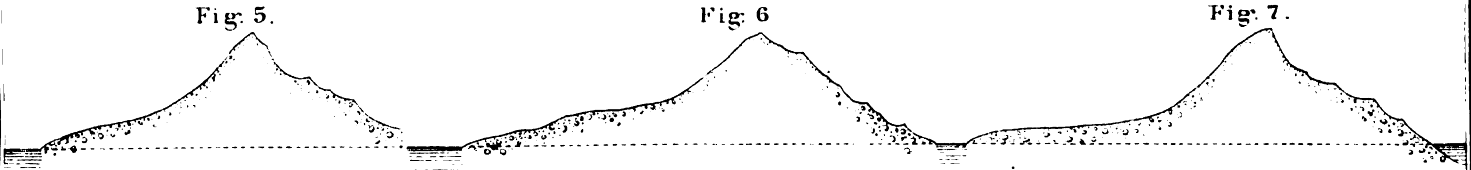
Fig. 4.



Vertical Scale 30 ft. 1 in.
Horizontal 200 . . .

SECTIONS OF SHINGLE LEVEE BETWEEN THIRD AND FOURTH CLIFFS.

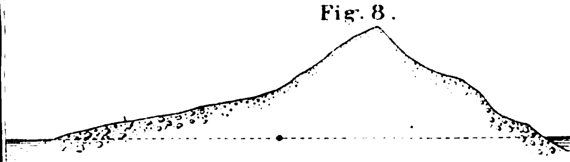
Fig. 5. Fig. 6 Fig. 7.



Sections 5.6.7.8. *Vertical Scale 30 ft. 1 in.*
Horizontal . 100 . . .

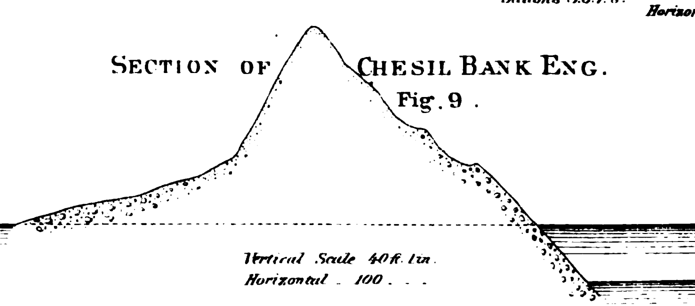
MEAN OF SECTIONS.

Fig. 8.



SECTION OF CHESIL BANK ENG.

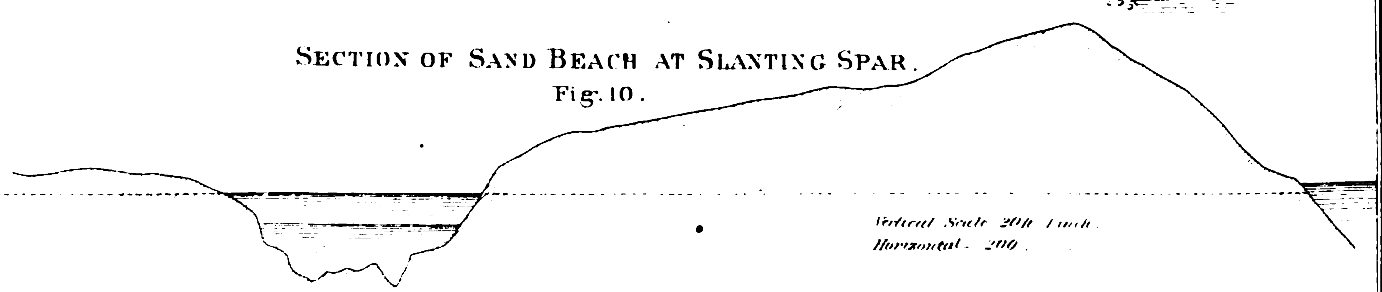
Fig. 9.



Vertical Scale 40 ft. 1 in.
Horizontal . 100 . . .

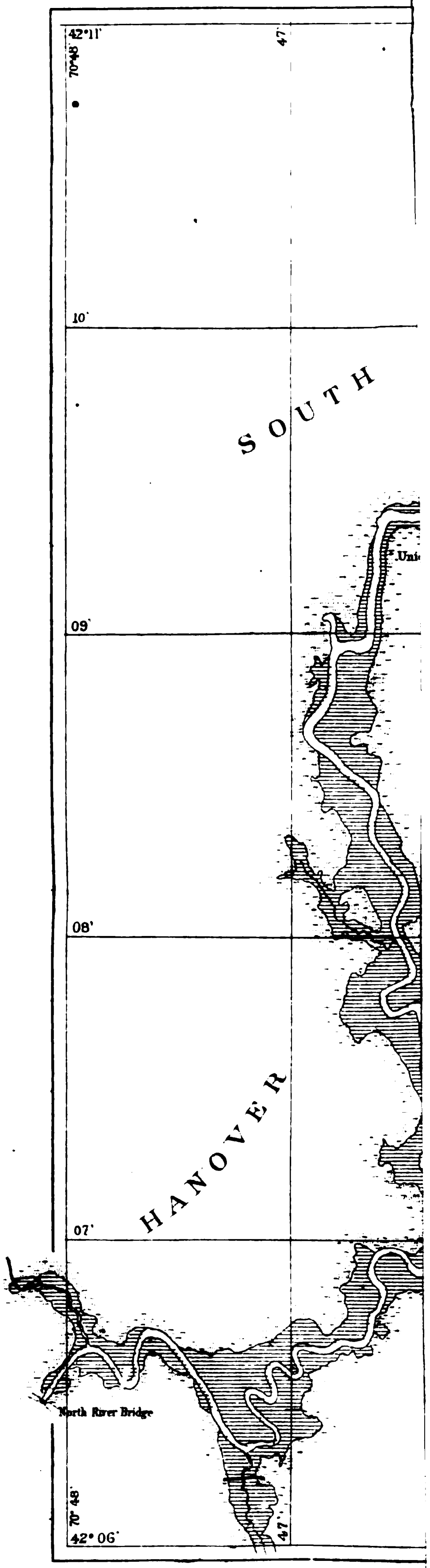
SECTION OF SAND BEACH AT SLANTING SPAR.

Fig. 10.



Vertical Scale 20 ft. 1 inch.
Horizontal . 200 .

To accompany report of H. Mitchell on the Reclamation of Tide Lands.



42°11'
70°48'
47'
10'
SOUTH
09'
08'
HANOVER
07'
North River Bridge
70°48'
42° 06'
47'

APPENDIX No. 6.

REPORT ON THE CONNECTION OF THE PRIMARY BASE LINES ON KENT ISLAND, MARYLAND, AND ON CRANEY ISLAND, VIRGINIA, AND ON THE DEGREE OF ACCURACY OF THE INTERVENING PRIMARY AND SUB-PRIMARY TRIANGULATIONS.

PREPARED IN MAY, 1871, BY CHARLES A. SCHOTT, ASSISTANT, COAST SURVEY.

The Craney Island verification base was measured in September, 1869; a detailed account of it, together with the resulting length, was reported under date of April 15, 1870. The triangulation between the two bases may be conceived as composed of two parts, the upper one, designated Part "VII," extending from the line South base Kent Island—Marriott to the line Costin—Back River Light; and the lower one, designated Part "VIII," connecting the last-named line, through a series of smaller triangles, with the verification base.

The distance between the middle of the base lines, when measured through the axis of the triangulation, is one hundred and fifty-seven statute miles. The conditions of the triangulation, inclusive of the correspondence of the base lines, were satisfied by application of the method of least squares, as generally explained in former reports on the primary triangulation between Maine and the Territory of Columbia.

The results of Part VI of immediately preceding operations are given in Coast Survey Report for 1866, Appendix No. 8.

The line Costin—Back River Light was taken as the junction-line of Parts VII and VIII; it is distant from the Craney Island base about twenty-five statute miles. After a long interval, operations were resumed in 1866 at the junction-line, and the triangulation completed in 1869.

Between South base Kent Island and the junction there are thirty-six triangles, measured between 1846 and 1853 by Assistant E. Blunt; the angles were measured by repetitions, chiefly by means of a 12-inch Simms theodolite, (No. 11.)

Between the junction and Craney Island there are twenty-one triangles, measured between 1866 and 1869 by Assistants R. D. Cutts and R. E. Halter;* all angles were measured by repetitions, and the greater number by a 12-inch Gambey theodolite, (No. 32.)

The conditions among the angular spaces measured at each station were first satisfied, and the probable error of each resulting direction was computed, as in Part VI, by the method used for directions, the separate results having been properly arranged for this purpose.

In the older operation, a station near Back River Light was used; but in resuming the work, its position was carefully transferred, both by angular and linear measures, to the center of the light-house. The necessary adjustment of this auxiliary work was attended to.

The accompanying sketches show the triangulation of Parts VII and VIII, also of the sub-primary stations Cape Charles Light and North end of measurement, and of the secondary station Hampton Seminary. It will be seen that the direction Costin to New Point Comfort has been rejected by the computer; it was found several seconds in error, due to an insufficient number of observations.

We have the following statistics of conditions in the geometrical figures of—

		Number of—			
		Conditional equations of—		Equations of correlatives.	Normal equations.
		Angles.	Sides.		
Part VII.	Kent Island to Back River Light	27	7	102	34
Part VIII.	Back River Light to Craney Island	15	7	51	22

* With a few measures by Assistant S. C. McCorkle.

The resulting length (in terms of the committee meter) of the line of junction, Costin to Back River Light, is as follows:

From the Kent Island base	$26758^m.432 \pm 0^m.38$
From the Craney Island base	$26758\ .176 \pm 0\ .43$

The difference, $0^m.256 \pm 0^m.57$, amounts to nearly $\frac{1}{104000}$ of the length.

If we desire to compare the base lines directly, we have—

Craney Island base, computed from the Kent Island base	$5136^m.622$
Craney Island base, measured	5136 .572
Difference	0 .050

The weighted mean and final length of the junction is consequently .... $26758^m.32 \pm 0^m.28$
[4.4274588 3]
± 45 6

The logarithmic constant in the length-equation for Part VII, in order to produce this weighted mean, is therefore —18·3, (units of the 7th place of decimals;) and for Part VIII, +23.3.

With this additional equation,* the number of normal equations in Part VII became 35, and that of Part VIII 23, and their solution and the substitution of resulting corrections to the directions produced an exact agreement between the base lines. It will thus be seen that, for any given distance in the triangulation between Maine and Virginia, we shall get the *same value*, no matter from which of the five *measured bases* we start. These base lines, when transferred by means of their respective branches of triangulation to a centrally-located line, for which the Fire Island base was chosen, compared as follows *before* the four length-equations involved had been introduced:

Linear discrepancies in the base lines of the Atlantic series of primary triangulation.

	Length of Fire Island base.
	Meters.
By the Epping base of 1857, through 430 statute miles of triangulation	14059.039
By the Massachusetts base of 1844, through 230 statute miles of triangulation	14058.916
By the Fire Island base of 1834, directly measured	14058.971
By the Kent Island base of 1844, through 263 statute miles of triangulation	14058.809
By the Craney Island base of 1869, through 420 statute miles of triangulation	14058.674

Four different kinds of apparatus were employed in the measures, that of the bases of 1844 being the same. 14059^m corresponds to 8.74 statute miles.

The effect of the introduction of the length-equation amounts, in Part VII, when *greatest*, to only 0″.054 in an angle, and in Part VIII to 0″.124.

The probable error of the measure of the Kent Island base is its $\frac{1}{228000}$ part; that of the starting-line South end Kent Island base—Marriott, its $\frac{1}{176000}$, (corresponding to $0^m.121$ in length;†) that of the line Costin—Back River Light its $\frac{1}{94000}$, and that of the measure of the Craney Island base its $\frac{1}{138000}$ part; hence the average probable error of the triangulation between Kent Island and Back River Light is its $\pm\frac{1}{122000}$ part, between Back River Light and Craney Island its $\pm\frac{1}{112000}$ part, and the average probable error of the whole triangulation lying between the base lines of Section III its $\pm\frac{1}{121000}$ part. This last uncertainty corresponds to nearly ±0.52 inch to the mile. From the nature of the case these numbers can only be regarded as tolerable approximations.

* It has 79 terms in Part VII, and 27 terms in Part VIII.

† The value $0^m.165$ corresponding to $\frac{1}{129000}$ is given in Coast Survey Report of 1866, page 50. The above value has been preferred after a re-discussion.

The usual statistical results bearing upon the degree of accuracy of the triangulation are the following:

Part.	No. of triangles.	Greatest error in true sum of angles of a triangle.	Average error in true sum of angles of a triangle.*	Number of— + errors.	Number of— − errors.	Probable error of a direction derived from triangle residuals.	Angles measured apparently too great.	Instruments used.
		"	"			"	"	
VII.......	31	4.662	1.678	11	20	±0.462	−0.28	Chiefly a 12-inch repeating theodolite by Simms, also a 10-inch by Simms, and a 12 and 10 inch by Gambey.
VIII......	19	6.18	2.47	14	5	±0.68	+0.40	A 12-inch Gambey almost exclusively.

In Part VIII many of the triangles are quite small, and a greater residual in the closing of such triangles is allowable. In this part, also, the measures, on the average, appear too great, contrary to previous experience with repeaters, but the defect seems to depend mainly upon the construction of the clamp and the firmness of the instrument.

If we deduct the probable observing error of a direction at each station, which is $\pm 0''.214$ in Part VII, and $\pm 0''.193$ in Part VIII, from the probable error of a direction derived from the closing of the triangles, we find the following triangle combination error: ϵ_Δ for Part VII $= \pm 0''.409$, and for Part VIII $= \pm 0''.650$.

In determining the relative weights to each direction, as required in establishing the conditional equations, the square of this quantity ϵ_Δ was added to the square of the probable observing error specially found for any particular direction, thus equalizing, in a great measure, the relative weights of the various directions. The extreme weights are in proportion of 1 to 2.4 in Part VII, and in the proportion of 1 to 1.6 in Part VIII.

The final corrections to the observed directions, as demanded by the least square adjustment of the geometrical figure of the triangulation, are given below.

	Greatest correction to any direction.	Average correction to— A direction.	Average correction to— An angle.
	"	"	"
Part VII............	2.57	0.61	0.86
Part VIII...........	2.91	0.73	1.03

The average length of a triangle side of Part VII† is 13.3 statute miles, and of Part VIII‡ 9.0 statute miles, and the sum total of the sides is 678 miles and 225 miles respectively.

The table of observed and corrected angles and of the resulting distances is arranged the same as for the preceding primary triangulation; the unit of length is the committee meter, for the length of which see the comparisons at Paris in 1867, (Coast Survey Report of 1867, Appendix No. 7.)

Adjustment of the sub-primary stations.—Cape Charles Light and North end of measurement.

Their connection with the primary triangulation is shown in Sub-sketch I. The position of the first-named point is determined by the intersection of five rays directed to it; that of the last-named point by a complete triangle, strengthened by one direction to Cape Charles Light. Four conditional equations are involved. The necessary corrections to the measured angles are shown in the accompanying nine triangles. Average correction to an angle $=1''.35$.

Adjustment of the secondary station, Hampton Seminary.

This position is determined by the intersection of eight rays, and consequently involves six conditional equations.

The necessary corrections to the measured angles are shown in the accompanying fourteen triangles. The average correction to an angle is $2''.85$.

* Obtained by means of the average square of the individual errors.
† Exclusive of side Marriott—South base. ‡ Exclusive of side Costin—Back River Light.

ATLANTIC SERIES OF PRIMARY TRIANGLES CONTINUED.

Resulting angles and distances between Kent Island, South Base, and Back River Light.

No. of triangle.	Name of station.	Observed angles. °	′	″	Corrections by adjustment. ″	Resulting angles, seconds. ″	Spherical excess of triangle. ″	Log. distances of opposite sides.	Distances, meters, (com.)	Distances, statute miles.
165	Poplar Island	62	47	38.643	—0.102	38.541	0.824	4.3284441 3	21303.165	13.24
	Marriott	40	51	09.199	—0.087	09.112		4.1950155 6	15668.072	9.74
	South Base	76	21	13.256	—0.085	13.171		4.3669261 0	23276.951	14.46
166	Blake	65	57	00.660	—0.127	00.533	0.951	4.3669261 0	23276.951	14.46
	Marriott	41	23	48.306	+0.094	48.400		4.2267425 2	16855.534	10.47
	Poplar Island	72	39	12.144	—0.126	12.018		4.3861487 2	24330.370	15.12
167	Hill's Point	45	12	43.828	+0.390	44.218	0.866	4.2267425 2	16855.534	10.47
	Blake	67	16	16.172	—0.268	15.904		4.3405472 9	21905.203	13.61
	Poplar Island	67	31	00.248	+0.496	00.744		4.3413230 4	21944.366	13.64
168	Wilson	56	13	54.992	+1.040	56.032	1.013	4.3413230 4	21944.366	13.64
	Blake	44	31	53.054	+0.720	53.774		4.2674718 7	18512.790	11.50
	Hill's Point	79	14	11.770	—0.563	11.207		4.4138581 4	25933.321	16.11
169	Travers	46	43	54.502	—0.335	54.167	0.571	4.3413230 4	21944.366	13.64
	Blake	21	35	46.732	+1.118	47.850		4.0450303 8	11092.524	6.89
	Hill's Point	111	40	17.787	+0.770	18.557		4.4472640 1	28006.834	17.40
170	Travers	114	32	02.799	+0.766	03.565	0.280	4.2674718 7	18512.790	11.50
	Wilson	33	01	49.603	—0.238	49.365		4.0450303 7	11092.524	6.89
	Hill's Point	32	26	06.017	+1.333	07.350		4.0380138 8	10914.752	6.78
171	Travers	67	48	08.297	+1.102	09.399	0.719	4.4138581 4	25933.321	16.11
	Wilson	89	15	44.595	+0.801	45.396		4.4472640 1	28006.834	17.40
	Blake	22	56	06.322	—0.398	05.924		4.0380138 8	10914.752	6.78
172	Calvert	53	08	45.006	+0.665	45.671	0.276	4.0380138 8	10914.752	6.78
	Wilson	78	47	51.610	+0.684	52.294		4.1264794 8	13380.720	8.31
	Travers	48	03	22.800	—0.489	22.311		4.0062900 3	10145.887	6.30
173	Meekin	83	42	04.318	+0.649	04.967	0.254	4.1264794 8	13380.720	8.31
	Calvert	48	00	53.696	—0.180	53.516		4.0002837 5	10006.536	6.22
	Travers	48	17	00.814	+0.957	01.771		4.0021097 9	10048.698	6.24
174	Cedar	55	31	20.760	—0.151	20.609	0.180	4.0021097 9	10048.698	6.24
	Calvert	89	07	52.306	—0.601	51.705		4.0859496 1	12188.482	7.57
	Meekin	35	20	47.431	+0.435	47.866		3.8483189 9	7052.109	4.38
175	Tom's Point	27	40	54.992	+0.691	55.683	0.405	4.0021097 9	10048.698	6.24
	Calvert	48	56			59.167		4.2125113 0	16312.154	10.14
	Meekin	103	22	04.522	+1.033	05.555		4.3231331 6	21044.236	13.08
176	Tom's Point	43	53	12.912	+0.794	13.706	0.468	4.0859496 1	12188.482	7.57
	Cedar	68	05	29.587	—0.514	29.073		4.2125113 0	16312.154	10.14
	Meekin	68	01	17.091	+0.598	17.689		4.2122980 6	16304.146	10.13
177	Tom's Point	16	12	17.920	+0.103	18.023	0.243	3.8483189 9	7052.109	4.38
	Cedar	123	36	50.347	—0.665	49.682		4.3231331 5	21044.235	13.08
	Calvert	40	10			52.538		4.2122980 6	16304.146	10.13
178	Point no Point	56	05	00.044	+1.817	01.861	0.936	4.3231331 6	21044.235	13.08
	Calvert	44	41			14.218		4.2512323 6	17833.327	11.08
	Tom's Point	79	13	44.017	+0.840	44.857		4.3964118 0	24912.184	15.48
179	Point no Point	1	46	27.557	+1.188	28.745	0.035	3.8483189 9	7052.109	4.38
	Calvert	4	30	18.997	+2.683	21.680		4.2526213 5	17890.453	11.12
	Cedar	173	43	08.819	+0.791	09.610		4.3964118 0	24912.184	15.48
180	Point no Point	54	18	32.487	+0.629	33.116	0.658	4.2122980 6	16304.146	10.13
	Cedar	62	40	00.834	—0.126	00.708		4.2512323 6	17833.327	11.08
	Tom's Point	63	01	26.097	+0.737	26.834		4.2526213 6	17890.454	11.12
181	Holland	53	59	54.063	+0.401	54.464	0.784	4.2512323 6	17833.327	11.08
	Point no Point	57	41	36.648	—0.854	35.794		4.2702422 8	18631.262	11.58
	Tom's Point	68	18	30.717	—0.191	30.526		4.3113866 3	20482.673	12.73
182	Point Lookout	70	23	10.564	+0.076	10.640	0.542	4.3113866 3	20482.673	12.73
	Point no Point	80	32	36.798	+0.836	37.634		4.3314044 4	21448.871	13.33
	Holland	29	04	12.206	+0.062	12.268		4.0238738 0	10565.105	6.56

Resulting angles and distances between Kent Island, South Base, and Back River Light—Continued.

No. of triangle.	Name of station.	Observed angles.			Corrections by adjustment.	Resulting angles, seconds.	Spherical excess of triangle.	Log. distances of opposite sides.	Distances, meters, (com.)	Distances, statute miles.
		°	′	″	″	″	″			
	Smith's Point Light	42	05	43.312	+1.822	45.134		4.3113866 3	20482.673	12.73
183	Point no Point	65	34	09.058	+0.675	09.733	1.379	4.4443328 1	27818.443	17.29
	Holland	72	20	05.001	+1.511	06.512		4.4640943 2	29113.494	18.09
	Smith's Point Light	50	18	42.100	+0.017	42.117		4.3314044 4	21448.871	13.33
184	Point Lookout	86	25	23.486	+1.192	24.678	1.039	4.4443328 2	27818.443	17.29
	Holland	43	15	52.795	+1.449	54.244		4.2811066 9	19103.225	11.87
	Smith's Point Light	8	12	58.788	—1.804	56.984		4.0238738 0	10565.105	6.56
185	Point Lookout	156	48	34.050	+1.268	35.318	0.202	4.4640943 3	29113.494	18.09
	Point no Point	14	58	27.740	+0.160	27.900		4.2811066 9	19103.225	11.87
	Shank	48	34	07.675	+0.968	08.643		4.3314044 4	21448.871	13.33
186	Point Lookout	48	37	24.060	—1.512	22.548	1.160	4.3317644 4	21466.658	13.34
	Holland	82	48	29.595	+0.374	29.969		4.4530561 6	28382.860	17.64
	Shank	89	57	09.650	+0.629	10.279		4.4443328 2	27818.443	17.29
187	Smith's Point Light	50	30	14.582	+0.380	14.962	0.966	4.3317641 3	21466.657	13.34
	Holland	39	32	36.800	—1.075	35.725		4.2482401 2	17710.879	11.01
	Shank	41	23	01.975	—0.340	01.635		4.2811066 9	19103.225	11.87
188	Smith's Point Light	100	48	56.682	+0.396	57.078	0.844	4.4530561 6	28382.860	17.64
	Point Lookout	37	47	59.426	+2.705	62.131		4.2482401 2	17710.879	11.01
	Tangier	46	39	06.479	+0.637	07.116		4.2482401 2	17710.879	11.01
189	Smith's Point Light	36	17	27.353	—0.677	26.676	0.641	4.1588233 0	14415.287	8.96
	Shank	97	03	26.351	+0.501	26.852		4.3832851 4	24170.473	15.02
	Windmill	44	32	21.938	+1.047	22.985		4.3832851 4	24170.473	15.02
190	Smith's Point Light	72	09	42.576	+0.772	43.348	1.799	4.5159215 6	32803.604	20.38
	Tangier	63	17	54.962	+0.504	55.466		4.4883450 8	30785.420	19.13
	Sandy Point	70	39	10.529	+0.016	10.545		4.5159215 6	32803.604	20.38
191	Windmill	50	02	40.907	—0.602	40.305	1.909	4.4257025 7	26650.329	16.56
	Tangier	59	18	11.387	—0.328	11.059		4.4756036 0	29895.347	18.58
	Wolftrap	62	46	10.056	+0.222	10.278		4.4756036 0	29895.347	18.58
192	Windmill	72	36	29.226	+0.341	29.567	1.712	4.5062948 0	32084.465	19.94
	Sandy Point	44	37	21.839	+0.028	21.867		4.3732232 1	23616.917	14.67
	Rosemary	83	19	45.784	+0.170	45.954		4.5062948 0	32084.465	19.94
193	Wolftrap	53	59	14.865	+0.004	14.869	1.444	4.4171327 4	26129.599	16.24
	Sandy Point	42	41	00.152	+0.469	00.621		4.3404402 2	21899.804	13.61
	New Point Comfort	66	55	49.465	—0.186	49.279		4.3404402 2	21899.804	13.61
194	Wolftrap	84	17	50.875	—0.357	50.518	0.634	4.3744840 9	23685.584	14.72
	Rosemary	28	46	20.300	+0.537	20.837		4.0590830 1	11457.319	7.12
	Back River Light	36	11	32.098	+0.214	32.312		4.3404402 2	21899.804	13.61
195	Wolftrap	73	26	31.830	+0.930	32.760	1.863	4.5508311 4	35549.307	22.09
	Rosemary	70	21	56.056	+0.735	56.791		4.5432085 2	34930.799	21.70
	Back River Light	41	23	55.290	+0.952	56.242		4.3744840 9	23685.584	14.72
196	New Point Comfort	97	00	29.722	—0.497	29.225	1.420	4.5508311 5	35549.308	22.09
	Rosemary	41	35	35.756	+0.197	35.953		4.3761495 4	23776.588	14.77
	Back River Light	5	12	23.192	+0.738	23.930		4.0590830 1	11457.319	7.12
197	New Point Comfort	163	56	19.187	—0.684	18.503	0.191	4.5432085 2	34930.799	21.70
	Wolftrap	10	51	19.045	—1.287	17.758		4.3761495 2	23776.587	14.77
	Costin	19	22			21.827		4.0590830 1	11457.319	7.12
198	New Point Comfort	103	49	10.583	+0.630	11.213	0.817	4.5255658 2	33540.213	20.84
	Wolftrap	56	48	28.266	—0.489	27.777		4.4609642 9	28904.422	17.96
	Costin	69	45	60.570	—1.892	58.678		4.5432085 2	34930.799	21.70
199	Back River Light	64	16	54.651	—1.209	53.442	2.139	4.5255658 2	33540.213	20.84
	Wolftrap	45	57	09.221	+0.798	10.019		4.4274588 3	26758.319	16.63
200	Costin	50	23			36.852		4.3761495 3	23776.588	14.77
	Back River Light	69	29	17.843	—0.471	17.372	1.514	4.4609642 9	28904.422	17.96
	New Point Comfort	60	07	08.604	—1.314	07.290		4.4274588 3	26758.319	16.63

Resulting angles and distances between the Craney Island Base and Back River Light.

No. of triangle.	Name of station.	Observed angles.			Corrections by adjustment.	Resulting angles, seconds.	Spherical excess of triangle.	Log. distances of opposite sides.	Distances, meters, (com.)	Distances, statute miles.
		°	′	″	″	″	″			
	Newport News, 1869	25	34	37.970	+2.089	40.059		3.7106733 6	5136.572	3.19
201	East Base	41	48	20.680	+1.523	22.203	0.096	3.8993285 6	7931.011	4.93
	West Base	112	36	57.260	+0.574	57.834		4.0407049 6	10982.595	6.82
	Sewall's Point, 1869	34	27	18.750	—1.030	17.720		3.7106733 6	5136.572	3.19
202	East Base	95	25	22.830	—0.455	22.375	0.091	3.9560948 7	9038.469	5.62
	West Base	50	07	18.720	+1.276	19.996		3.8430725 9	6967.430	4.33
	Sewall's Point, 1869	87	04	07.940	—0.154	07.786		4.0407049 6	10982.595	6.82
203	East Base	53	37	02.150	—1.978	00.172	0.157	3.9471054 1	8853.305	5.50
	Newport News, 1869	39	18	53.470	—1.271	52.199		3.8430725 8	6967.429	4.33
	Sewall's Point, 1869	52	36	49.190	+0.876	50.066		3.8993285 6	7931.011	4.93
204	West Base	62	29	38.540	—0.703	37.837	0.162	3.9471054 1	8853.305	5.50
	Newport News, 1869	64	53	31.440	+0.819	32.259		3.9560948 7	9038.469	5.62
	Old Point Comfort Light	53	21	41.230	—2.583	38.647		3.9471054 1	8853.305	5.50
205	Sewall's Point, 1869	92	44	37.680	—1.904	35.776	0.138	4.0422118 8	11020.769	6.85
	Newport News, 1869	33	53	47.410	—1.695	45.715		3.7891007 2	6153.196	3.82
	Cumming's Point	83	51	36.010	—1.197	34.813		3.9471054 1	8853.305	5.50
206	Sewall's Point, 1869	45	56	56.220	—1.090	55.130	0.111	3.8061619 7	6399.735	3,98
	Newport News, 1869	50	11	31.710	—1.542	30.168		3.8350732 9	6840.271	4.25
	Cumming's Point	143	29	42.820	—1.699	41.121		4.0422118 8	11020.769	6.85
207	Old Point Comfort Light	20	12	33.320	+1.156	34.476	0.050	3.8061619 8	6399.735	3.98
	Newport News, 1869	16	17	44.300	+0.153	44.453		3.7158493 4	5198.156	3.23
	Cumming's Point	59	38	06.810	—0.501	06.309		3.7891007 2	6153.196	3.82
208	Old Point Comfort Light	73	34	14.550	—1.427	13.123	0.078	3.8350733 1	6840.271	4.25
	Sewall's Point, 1869	46	47	41.460	—0.814	40.646		3.7158493 7	5198.157	3.23
	Willoughby's Point, 1869	21	07	39.310	+0.461	39.771		3.7158493 5	5198.156	3.23
209	Cumming's Point	26	22	16.610	—0.684	15.926	0.062	3.8065688 2	6405.733	3.98
	Old Point Comfort Light	132	30	01.960	—0.595	04.365		4.0266293 0	10632.351	6.61
	Willoughby's Point, 1869	58	29	47.250	—0.940	46.310		3.7891007 2	6153.196	3.82
210	Sewall's Point, 1869	62	34	22.280	+0.254	22.534	0.086	3.8065688 4	6405.733	3.98
	Old Point Comfort Light	58	55	50.410	+0.832	51.242		3.7911030 6	6181.631	3.84
	Willoughby's Point, 1869	37	22	07.940	—1.402	06.538		3.8350733 0	6840.271	4.25
211	Sewall's Point, 1869	109	22	03.740	—0.560	03.180	0.101	4.0266293 1	10632.351	6.61
	Cumming's Point	33	15	50.200	+0.183	50.383		3.7911030 5	6181.631	3.84
	Back River Light	22	17	38.050	—0.076	37.974		3.7911030 5	6181.631	3.84
212	Willoughby's Point, 1869	96	53	15.160	—0.784	14.376	0.222	4.2089096 6	16177.435	10.05
	Sewall's Point, 1869	60	49	07.820	+0.052	07.872		4.1531101 5	14226.896	8.84
	Cape Henry Light	8	05	43.570	—1.416	42.154		3.8065688 3	6405.733	3.98
213	Willoughby's Point, 1869	142	12	47.000	—0.294	46.706	0.225	4.4451872 6	27873.228	17.32
	Old Point Comfort Light	29	41	31.610	—0.245	31.365		4.3528206 8	22533.086	14.00
	Cape Henry Light	28	02	45.440	+0.226	45.666		4.1531101 5	14226.896	8.84
214	Willoughby's Point, 1869	103	49	19.090	—0.452	18.638	0.791	4.4680852 3	29382.262	18.26
	Back River Light	48	07	55.790	+0.697	56.487		4.3528207 1	22533.088	14.00
	Costin	52	05	56.710	—0.197	56.513		4.4451872 6	27873.228	17.32
215	Cape Henry Light	75	29	09.030	+0.690	09.720	1.919	4.5339845 9	34196.731	21.25
	Old Point Comfort Light	52	24	55.960	—0.274	55.686		4.4470439 5	27992.646	17.39
	Costin	64	51	60.720	—1.372	59.348		4.4680852 3	29382.262	18.26
216	Cape Henry Light	55	32	07.160	—0.953	06.207	1.723	4.4274588 4	26758.320	16.63
	Back River Light	59	35	56.840	—0.672	56.168		4.4470439 8	27992.648	17.39
	Pleasure House Point, 1867	63	56	59.980	—0.270	59.710		4.4470439 6	27992.647	17.39
217	Costin	21	51	05.370	—1.156	04.214	0.823	4.0643407 4	11596.869	7.21
	Cape Henry Light	94	11	58.070	—1.171	56.899		4.4924020 6	31074.351	19.31
	Pleasure House Point, 1867	121	43	07.180	—0.509	06.671		4.4680852 3	29382.262	18.26
218	Back River Light	19	37	02.680	+0.498	03.178	0.541	4.0643407 2	11596.868	7.21
	Cape Henry Light	38	39	50.910	—0.218	50.692		4.3340466 4	21579.761	13.41
	Pleasure House Point, 1867	57	46	07.200	—0.239	06.961		4.4274588 4	26758.320	16.63
219	Back River Light	79	12	59.520	—0.174	59.346	1.441	4.4924020 7	31074.351	19.31
	Costin	43	00	55.350	0.216	55.134		4.3340466 4	21579.761	13.41

Resulting angles and distances between the Craney Island Base and Back River Light—Continued.

No. of triangle.	Name of station.	Observed angles.			Corrections by adjustment.	Resulting angles, seconds.	Spherical excess of triangle.	Log. distances of opposite sides.	Distances, meters, (com.)	Distances, statute miles.
		°	′	″	″	″	″			
	Pleasure House Point, 1867	84	54	49. 670	—0. 697	48. 973		4. 5339845 9	34196. 731	21. 25
220	Old Point Comfort Light	64	50			20. 088	1. 360	4. 4924020 4	31074. 349	19. 31
	Costin	30	14	51. 340	+0. 959	52. 299		4. 2379045 3	17294. 362	10. 75
	Pleasure House Point, 1867	148	51	49. 650	—0. 967	48. 683		4. 4451872 6	27873. 228	17. 32
221	Old Point Comfort Light	12	25			24. 400	0. 263	4. 0643407 1	11596. 868	7. 21
	Cape Henry Light	18	42	49. 040	—1. 860	47. 180		4. 2379045 3	17294. 362	10. 75

Resulting angles and distances of sub-primary triangulation in the vicinity of Cape Charles.

	Old Point Comfort Light (angles computed)	118	14			20. 178		4. 1531102	14226. 896	8. 84
	Back River Light (angles computed)	23	22			11. 898	0. 144	3. 8065687	6405. 732	3. 98
	Willoughby's Point, 1869	38	23	27. 910	+0. 158	28. 068		4. 0012529	10028. 892	6. 23
	Cape Charles Light	13	23			13. 336		4. 0012529	10028. 892	6. 23
	Old Point Comfort Light	51	18	56. 840	—1. 196	55. 644	0. 779	4. 5290796	33812. 68	21. 01
	Back River Light	115	17	51. 864	—0. 065	51. 799		4. 5928685	39162. 32	24. 33
	Cape Charles Light	38	37			21. 611		4. 3340466	21579. 761	13. 41
	Pleasure House Point, 1867	77	57	51. 508	+1. 946	53. 454	1. 658	4. 5290796	33812. 68	21. 01
	Back River Light	63	24	46. 658	—0. 065	46. 593		4. 4901930	30916. 69	19. 21
	Cape Charles Light	25	14			08. 275		4. 2379045	17294. 362	10. 75
	Pleasure House Point, 1867	105	06	33. 520	+1. 946	35. 466	1. 311	4. 5928685	39162. 32	24. 33
	Old Point Comfort Light	49	39	16. 374	+1. 196	17. 570		4. 4901930	30916. 69	19. 21
	Cape Charles Light	58	12			31. 158		4. 4680852	29382. 262	18. 26
	Cape Henry Light	77	59	48. 240	—1. 066	47. 174	1. 747	4. 5290796	33812. 68	21. 01
	Back River Light	43	47	43. 480	—0. 065	43. 415		4. 3788394	23924. 31	14. 87
	Cape Charles Light	44	49			17. 823		4. 4451873	27873. 228	17. 32
	Cape Henry Light	97	56	51. 752	—1. 066	50. 686	1. 678	4. 5928686	39162. 33	24. 33
	Old Point Comfort Light	37	13	51. 973	+1. 196	53. 169		4. 3788395	23924. 31	14. 87
	Cape Charles Light	19	35			09. 547		4. 0643407	11596. 869	7. 21
	Cape Henry Light	116	39	38. 932	—1. 066	37. 866	0. 630	4. 4901932	30916. 71	19. 21
	Pleasure House Point, 1867	43	45	15. 163	—1. 946	13. 217		4. 3788396	23924. 32	14. 87
	North end of measurement	41	21	37. 020	—1. 523	35. 497		4. 0643407	11596. 869	7. 21
	Pleasure House Point, 1867	30	01	13. 587	—0. 438	13. 149	0. 245	3. 9435162	8780. 44	5. 46
	Cape Henry Light	108	37	12. 338	—0. 739	11. 599		4. 2209314	16631. 50	10. 33
	North end of measurement	74	55	52. 110	—0. 296	51. 814		4. 4901931	30916. 71	19. 21
	Pleasure House Point, 1867	73	46	28. 750	—2. 384	26. 366	1. 254	4. 4877364	30742. 30	19. 10
	Cape Charles Light	31	17			43. 074		4. 2209314	16631. 50	10. 33
	North end of measurement	33	34	15. 090	+1. 226	16. 316		4. 3788395	23924. 32	14. 87
	Cape Henry Light	134	43	08. 730	+1. 805	10. 535	0. 379	4. 4877364	30742. 30	19. 10
	Cape Charles Light	11	42			33. 528		3. 9435163	8780. 44	5. 46

Resulting angles and distances of secondary triangulation in the vicinity of Hampton Roads.

	Willoughby's Point, 1869 (computed)	114	41			06. 98		4. 3340466	21579. 76	13. 41
	Back River Light	28	30	53. 31		53. 31	0. 37	4. 0545354	11337. 97	7. 04
	Pleasure House Point, 1867 (computed)	36	47			60. 08		4. 1531101	14226. 90	8. 84
	Willoughby's Point, 1869 (computed)	33	15			52. 89		3. 8430726	6967. 43	4. 33
	East Base (computed)	29	07			13. 31	0. 10	3. 7911030	6181. 63	3. 84
	Sewall's Point, 1869	117	36	53. 90		53. 90		4. 0513642	11255. 48	6. 99
	Willoughby's Point, 1869 (computed)	10	51			48. 34		4. 0643407	11596. 87	7. 21
	Cape Henry Light (computed)	10	37			05. 03	0. 12	4. 0545356	11337. 98	7. 04
	Pleasure House Point, 1867 (computed)	158	31			06. 75		4. 3528208	22533. 09	14. 00
	Pleasure House Point, 1867 (computed)	32	17			09. 00		4. 0513642	11255. 48	6. 99
	East Base (computed)	32	33			05. 54	0. 29	4. 0545355	11337. 97	7. 04
	Willoughby's Point, 1869	115	09	45. 75		45. 75		4. 2804052	19072. 39	11. 85

Resulting angles and distances of secondary triangulation in the vicinity of Hampton Roads—Continued.

No. of triangle.	Name of station.	Observed angles.			Corrections by adjustment.	Resulting angles, seconds.	Spherical excess of triangle.	Log. distances of opposite sides.	Distances, meters, (com.)	Distances, statute miles.
		°	'	"	"	"	"			
	Institute	11	17			45.77		4.0643407	11596.868	7.21
	Cape Henry Light	20	00	07.30	+0.44	07.74	0.31	4.3064509	20251.21	12.58
	Pleasure House Point, 1867	148	42	12.84	—6.04	06.80		4.4879333	30756.24	19.11
	Institute	23	18			56.10		4.3528207	22533.09	14.00
	Cape Henry Light	9	23	02.27	+0.44	02.71	0.29	3.9676754	9282.72	5.77
	Willoughby's Point, 1869	147	18	00.00	+1.48	01.48		4.4879330	30756.22	19.11
	Institute	12	01			10.33		4.0545354	11337.97	7.04
	Pleasure House Point, 1867	9	48	53.91	+6.04	59.95	0.10	3.9676742	9282.70	5.77
	Willoughby's Point, 1869	158	09	48.34	+1.48	49.82		4.3064499	20251.16	12.58
	Institute	49	20			32.78		4.4470440	27992.646	17.39
	Costin	56	27	42.70	—2.54	40.16	2.10	4.4879332	30756.23	19.11
	Cape Henry Light	74	11	49.60	—0.44	49.16		4.5502893	35504.98	22.06
	Institute	60	38			18.55		4.4924021	31074.351	19.31
	Costin	34	36	38.49	—2.54	35.95	1.59	4.3064508	20251.20	12.58
	Pleasure House Point, 1867	84	45	13.13	—6.04	07.09		4.5502893	35504.98	22.06
	Institute	64	29			43.73		4.2804052	19072.39	11.85
	Pleasure House Point, 1867	42	06	02.91	+6.04	08.95	0.66	4.1513051	14167.89	8.80
	East Base	73	24	06.85	+1.13	07.98		4.3064501	20251.17	12.58
	Institute	52	28			33.39		4.0513642	11255.48	6.99
	Willoughby's Point, 1869	86	40	25.91	—1.48	24.43	0.26	4.1513053	14167.90	8.80
	East Base	40	51	01.31	+1.13	02.44		3.9676749	9282.71	5.77
	Institute	41	33			41.89		3.7911030	6181.63	3.84
	Willoughby's Point, 1869	53	24	33.02	+1.48	31.54	0.12	3.8739770	7481.30	4.65
	Sewall's Point, 1869	85	01	46.00	+0.69	46.69		3.9676748	9282.71	5.77
	Institute	10	54			51.51		3.8430726	6967.429	4.33
	Sewall's Point, 1869	157	21	20.10	—0.69	19.41	0.05	4.1513054	14167.90	8.80
	East Base	11	43	48.00	+1.13	49.13		3.8739774	7481.31	4.65
	Institute	61	39			39.78		3.9471054	8853.305	5.50
	Sewall's Point, 1869	70	17	12.31	—0.69	11.62	0.16	3.9763166	9469.27	5.88
	Newport News, 1869	48	03	12.74	—3.98	08.76		3.8739772	7481.30	4.65
	Institute	50	44			48.26		4.0407050	10982.595	6.82
	East Base	41	53	12.17	—1.13	11.04	0.26	3.9763166	9469.27	5.88
	Newport News, 1869	87	22	04.94	—3.98	00.96		4.1513053	14167.90	8.80
	Institute	4	26			37.69		3.8061620	6399.735	3.98
	Newport News, 1869	2	08	17.43	+3.98	21.41	0.01	3.4890098	3083.26	1.92
	Cumming's Point	173	25	00.00	+0.91	00.91		3.9763161	9469.26	5.88
	Institute	66	06			17.47		3.8350733	6840.271	4.25
	Sewall's Point, 1869	24	20	17.18	—0.69	16.49	0.05	3.4890111	3083.27	1.92
	Cumming's Point	89	33	25.18	+0.91	26.09		3.8739772	7481.30	4.65
	Institute	107	39			59.36		4.0266293	10632.351	6.61
	Willoughby's Point, 1869	16	02	26.48	—1.48	25.00	0.07	3.4890110	3083.27	1.92
	Cumming's Point	56	17	34.80	+0.91	35.71		3.9676750	9282.71	5.77

APPENDIX No. 7.

LOCAL DEFLECTIONS OF THE ZENITH IN THE VICINITY OF WASHINGTON CITY. REPORTED FEBRUARY 9, 1870, BY CHARLES A. SCHOTT, ASSISTANT, COAST SURVEY.

The following results of deflections of the direction of gravity in the vicinity of the District of Columbia are respectfully submitted:

The comparatively large number of astronomical stations clustered in the vicinity of Washington appeared to me to make it desirable to compare the astronomical and geodetic results, with a view of ascertaining the amount and direction of the deflection of the plumb-line at these stations.

The astronomical results had previously been revised, and the following tables contain the comparisons in latitude, in azimuth, and in longitude.

The probable errors given are those resulting *immediately* from the astronomical operations, and are undoubtedly too small; they are affected with constant errors to some extent, the zenith-telescope latitudes, for instance, giving, in some cases, slightly greater results for the smaller zenith distances, and the zenith-sector latitudes giving a small but sensible difference between results from north and south stars. The second line of probable errors in the azimuthal comparisons take in the additional uncertainty of the horizontal angles connecting the mark with the triangulation, but not the accumulated errors depending upon the triangulation. The probable error of the telegraphic-longitude results is only approximately known.

The geodetic results, in all cases, are those of the final least square adjustment of the primary triangulation. The geodetic latitude is the mean of twenty latitudes, measured in Sections I and II, between Cooper ($\varphi=45^\circ$) and Sandford ($\varphi=41\frac{1}{2}^\circ$). The geodetic azimuth is the mean of twenty-five azimuths, measured in the same sections, between Howard ($\lambda=67\frac{1}{2}^\circ$) and West Hills ($\lambda=73\frac{1}{2}^\circ$). The geodetic longitude is that of Cambridge obtained by means of the Atlantic telegraph.

The column headed A–G contains the differences of the astronomical and geodetic results, and the last column, headed A–G′, contains the difference of the astronomical and geodetic results after the latter have been changed to make $\Sigma(A-G)=0$, and to that extent the following results for deflection of plumb-line are *relative* only.

In the last two columns of the latitude comparisons, a + sign indicates a deflection of the zenith to the northward (of the normal or regular zenith, as depending on Bessel's ellipsoid); in the last two columns of the azimuth comparisons, a + sign indicates a deflection of the meridian to the eastward; and in the last two columns of the longitude comparisons, a + sign indicates a deflection of the zenith to the westward.

Latitude comparisons (arranged according to longitude).

Name of station.	Year.	Instrument.	Astronomical latitude.	Probable error.	Geodetic latitude.	A–G	A–G′
			° ′ ″	″	° ′ ″	″	″
Taylor	1847	Zenith telescope	38 59 45.97	±0.11	38 59 45.54	+0.43	+0.26
Marriott	1846-9	Zenith telescope	38 52 24.82	0.06	38 52 24.67	+0.15	−0.02
Webb	1850	Zenith sector	39 05 25.46	0.04	39 05 23.74	+1.72	+1.55
Hill	1850	Zenith sector	38 53 52.85	0.05	38 53 52.03	+0.82	+0.65
Soper	1850	Zenith sector	39 05 10.59	0.09	39 05 09.02	+1.57	+1.40
Seaton	1850	Zenith telescope	38 53 25.17	0.17	38 53 26.08	−0.91	−1.08
Four-and-a-half Street Observatory	1852	Zenith telescope	38 53 30.70	0.11	38 53 31.24	−0.54	−0.71
United States Naval Observatory	1861-4	Mural circle	38 53 38.78	0.10	38 53 39.37	−0.59	−0.76
Causten	1851	Zenith sector	38 55 32.51	0.04	38 55 32.42	+0.09	−0.08
Georgetown College Observatory	1846	Meridian circle	38 54 26.00	....	38 54 27.06	−1.06	−1.23
					$\frac{1}{10}\Sigma(A-G)$	+0.17	0.00

Azimuth comparisons (arranged according to latitude).

Name of station	Year.	Instrument.	Astronomical azimuth of mark.	Probable error.*	Geodetic azimuth.	A−G	A−G′
			° ′ ″	″	° ′ ″	″	″
Webb	1850	30-inch theodolite.	186 07 45.87	±0.21 0.28	186 07 37.48	+ 8.39	+0.03
Soper	1850	30-inch theodolite.	358 19 38.53	±0.29 0.40	358 19 32.23	6.30	−2.06
Causten	1851	30-inch theodolite.	210 53 00.26	±0.37 0.44	210 52 54.85	5.41	−2.95
Hill	1850	30-inch theodolite.	219 46 58.06	±0.30 0.35	219 46 49.16	8.90	+0.54
Seaton	1868–9	30-inch theodolite.	169 58 46.58	±0.18 0.44	169 58 34.95	11.63	+3.27
Marriott	1849	24-inch theodolite.	179 01 32.33	±0.48 0.53	179 01 22.80	+ 9.53	+1.17
					$\frac{1}{6}\Sigma$(A−G)....	+ 8.36	0.00

* The number in the second line to each station gives the probable error of the astronomical operation proper when combined with that connecting it with a line of the triangulation.

Longitude comparisons.

Name of station.	Year.	Instrument.	Astronomical longitude.	Probable error.	Geodetic longitude.	A−G	A−G
			° ′ ″	″	° ′ ″	″	″
Seaton	1867	Transit	76 59 51.30	±3.45	77 00 01.69	−10.39	−1.51
United States Naval Observatory, dome	1867	Meridian circle	77 03 00.90	3.45	77 03 08.28	− 7.38	+1.50
					$\frac{1}{2}\Sigma$(A−G)....	− 8.88	0.00

Let

$\Delta\varphi$=station-error in latitude;
$\Delta\lambda$=station-error in longitude;
Δa=station-error in azimuth; and
Δpv=deflection of zenith in the plane of the prime vertical, then—

$-\Delta pv=\Delta a \cot\varphi$ and Δz=deflection of zenith$=\sqrt{(\Delta pv)^2+(\Delta\varphi)^2}$
$\Delta pv=\Delta\lambda\cos\varphi$ and a_z=azimuth of disturbed zenith, counted from south by west.
$\Delta a=-\Delta\lambda\sin\varphi$

The total amount of deflection, and the azimuth of the disturbed from the undisturbed zenith, is readily found from the combination of $\Delta\varphi$ and Δpv at each station.

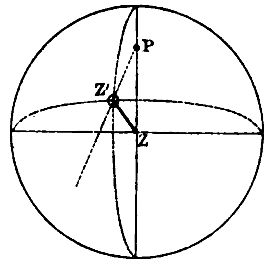
We have, by means of the quantities A−G′,

Station.	Δa	Δpv	$\Delta\phi$	Δz	az
	″	″	″	″	°
Webb	+0.03	−0.04	+1.55	1.55	181
Soper	−2.06	+2.54	+1.40	2.90	119
Causten	−2.95	+3.65	−0.08	3.65	89
Hill	+0.54	−0.67	+0.65	0.93	226
Seaton	+3.27	−4.05	−1.08	4.19	285
Marriott	+1.17	−1.45	−0.02	1.45	271

The quantities $\triangle z$ and az are plotted on the accompanying Plate; the disturbed zenith is indicated by a circle, and the line joining it and the station gives, in direction and distance (relative), the deflection of the vertical.

If we consider the quantities (A−G), we find, in the first place, a good accordance in the Section I and Section III latitudes; and, secondly, a tolerably good accordance between the azi-

muths and longitudes. We also notice that (A—G), for the azimuths, have all a + sign (or the zeniths are thrown toward the east), and average 8″.36; and converting this into a longitudinal quantity (by $\Delta\lambda = -\Delta\alpha$ cosec φ), we find —13″.3, whereas the telegraphic result gave —10″.1, leaving only 0ˢ.21 unaccounted for. A general deflection of the plumb-line to the westward (zenith east) in the vicinity of the District might be accounted for by the attraction of the Alleghanies and the deficiency in attraction of the ocean, if the case in Section I were not of an analogous character; we must therefore look upon it as a differential phenomenon.



With a view of facilitating an estimation how far the visible irregularities of the surface might account for the observed deflections of the plumb-line, an excellent sketch (No. 23) of the topography of the surrounding country has been compiled by Mr. A. Lindenkohl, showing the hypsometrical features by contour-lines 100 feet apart. On this chart the deflection of the vertical is shown in proportional scale, the disturbed zenith being marked by a small ring, and the dotted line connecting it and the station indicates the amount and direction of the disturbance.

If it was desirable at present to submit this subject to a further scrutiny, we could, with the material on hand, make a computation of the local attractions, depending on the visible irregularities of the ground, for one or all of the astronomical stations.

APPENDIX No. 8.

REPORTS OF OBSERVATIONS OF THE ECLIPSE OF THE SUN ON AUGUST 7, 1869, MADE BY PARTIES OF THE UNITED STATES COAST SURVEY, AT THE FOLLOWING PRINCIPAL STATIONS: BRISTOL, TENNESSEE, IN CHARGE OF ASSISTANT R. D. CUTTS; SHELBYVILLE, KENTUCKY, IN CHARGE OF PROFESSOR J. WINLOCK AND ASSISTANT G. W. DEAN; SPRINGFIELD, ILLINOIS, IN CHARGE OF ASSISTANT C. A. SCHOTT, UNDER THE IMMEDIATE DIRECTION OF THE SUPERINTENDENT OF THE SURVEY; DES MOINES, IOWA, IN CHARGE OF ASSISTANT J. E. HILGARD; AND KOHKLUX, CHILKAHT RIVER, ALASKA, IN CHARGE OF ASSISTANT G. DAVIDSON. ILLUSTRATED BY WOOD-CUTS AND PLATES Nos. 24, 25, AND 26.

GENERAL PATH OF THE ECLIPSE.—(*Sketch No.* 24.)

The large sketch shows the central line of the eclipse and the limiting lines of totality in the United States, the same things being shown for Alaska in the small sketch in the corner. These maps also show the oval outline of the instantaneous shadow of the moon at every successive minute of Washington mean time. These ovals are drawn by a graphical method devised by Mr. C. S. Peirce, which is explained in the account of the observations of the eclipse published in the Annals of the Observatory of Harvard College. The object of the map must not be mistaken. It is not intended to show the precise latitude and longitude at which the eclipse lasts for two minutes, one minute, or is instantaneous, although it will answer this purpose approximately. But the particular use which it is meant to serve is to predict the times of contact at any given place with sufficient accuracy to afford a judgment as to the relative advantages of two posts of observation, and also to give warning to the observer of the beginning and end of the eclipse. It is highly desirable, before an eclipse, to have a means of multiplying such predictions without loss of time, especially when the geographical positions are not well determined at the outset, and are successively improved before the final decision in regard to a station for observation is made. In order to use such a map, it is only necessary to lay down a graduated scale upon the line passing through the given geographical position from the moon's shadow for one minute to the moon's shadow for the next, parallel to the line of central eclipse between those minutes; and to measure the distance on the map between the two shadows, as well as the distance from the shadow at the preceding of the two minutes to the geographical position. Then the ratio of the latter distance to the former is equal to the ratio in which the instant of contact at that place divides the interval between the two successive minutes. As an example, let it be required to find the time of the beginning and end of the totality for the point defined by longitude=10°, latitude=39°. This point lies outside of an oval the center of which is marked $5^{h}\ 57^{m}$, and inside of an oval the center of which is marked $5^{h}\ 58^{m}$; also inside an oval the center of which is marked $6^{h}\ 00^{m}$, and outside one whose center is marked $6^{h}\ 01^{m}$. The totality, therefore, begins at this point between $5^{h}\ 57^{m}$ and $5^{h}\ 58^{m}$, and ends at $6^{h}\ 00^{m}$ and $6^{h}\ 01^{m}$. Then, first placing the scale parallel to the central line from $5^{h}\ 57^{m}$ to $5^{h}\ 58^{m}$, and so that the point is on the edge of it, we measure the distance from the preceding side of the shadow for the first minute to the preceding side of that for the second minute, and also the distance from the shadow to the first instant to the point. These distances are 0.84 inch and 0.52 inch, and therefore the time of first internal contact is $5^{h}\ 57\frac{52}{84}{}^{m}$, or $5^{h}\ 57^{m}\ 37^{s}$. Next placing the scale parallel to the central line from $6^{h}\ 00^{m}$ to $6^{h}\ 01^{m}$, and so as to run through the point, we measure the distance from the following side of the shadow for the former minute to the following side of the shadow for the latter minute, and also the distance from the former shadow to the point. These distances are 0.95 inch and 0.22 inch, and therefore the time of last internal contact is $6^{h}\ 00\frac{22}{95}{}^{m}$, or $6^{h}\ 00^{m}\ 14^{s}$. In this way the duration of totality can generally be determined to the nearest second except for points very near the limits.

OBSERVATIONS AT BRISTOL, TENNESSEE.

WASHINGTON, *August* 19, 1869.

SIR: I respectfully submit the following report of the operations and results of the party under my charge, in execution of your instructions to observe the solar eclipse of August 7, at some point in the mountains of Southwestern Virginia, where they would be crossed by the central line of the eclipse. (See Plate No. 24).

On the 25th of July, the party reached Bristol, which, according to the most authentic maps, was in close vicinity to the line of greatest obscuration; and on the 26th and 27th preliminary observations were taken to ascertain whether the position of the town was correctly laid down. The results being of a satisfactory character, a site for an observatory and for observing the eclipse was selected; the building was put up; and, between the 28th of July and the 5th of August, the latitude and longitude of the station were determined, the former by twelve pairs of stars, and the latter by the transmission of time-signals to the Naval Observatory, at Washington, on the nights of the 29th and 31st. A third determination of the difference of longitude between the two places was secured on the night following the eclipse. For the details of this operation reference is made to the report of Assistant A. T. Mosman.

Bristol is situated between the Cumberland and Alleghany Mountains, on the Virginia and Tennessee Railroad, and immediately on the boundary line, as at present recognized, between Virginia and Tennessee. It may be said to comprise two separate towns—Bristol, in Tennessee, and Goodson, in Virginia; the main street, which alone separates the two, being laid out along the line of the State-boundary. The observatory was erected on a bare ridge lying to the westward of and adjoining Goodson, about one-third of a mile from the telegraph-office, 320 yards north of the State-line, 82 feet above the railroad-track, and 1,760 feet above the sea. An unobstructed view to the westward was obtained, and sufficient elevation to command an extensive view of the surrounding country and mountains. (See Plate 25, Fig. 1, showing the vicinity of the station.)

The zenith-telescope and transit were mounted on solid piers, composed of brick and cement. The times of the commencement and the end of the eclipse and of the total phase were computed for the latitude and longitude of the observatory, as approximately determined by the 3d of August, using the formulæ and tables contained in the "Supplement to the American Ephemeris for 1869." The final reduction of all the observations and comparisons decreased the approximate latitude by $1''.6$ and increased the longitude by $0^s.25$.

A programme of "what to observe" was prepared and arranged in the order in which the phenomena would occur, and special classes assigned to each observer. As the party was small and organized almost entirely for what may be termed precision or time observations, many of the physical phenomena, usually observed on such occasions, although included in the programme and more fully explained to those who volunteered or desired to observe them, were not intended to be specially observed, on the ground that, if too much duty was imposed on any one observer, none might be thoroughly performed. Hence, the examination of the sun's disk, its colors and spots, during the different phases of the eclipse, the colors exhibited by the corona, the degree of darkness during totality, and the changes and gradations in the coloring of the landscape before and after totality, the effect of the obscuration upon animals, &c., were omitted or only incidentally observed, for the reason that they could not be properly or reliably attended to without interfering with a more desirable class of observations.

On the afternoon of the 6th of August, the telescopes were placed temporarily in position, and every possible preparation made to secure success in the observations to be taken on the next day.

August 7, 1869.—The telescope used by me was zenith-telescope No. 2, made by Troughton & Simms. It was mounted on the brick pier on which it had been employed in the determination of the latitude; the observatory having been so built that its western end might be removed for observing the eclipse. The object-glass was 3½ inches in diameter, the focal length 54 inches, and the amplifying-power about 28. Box-chronometer Hutton No. 215, running to mean time, was placed close by, and the times, as called by me, were noted and recorded by Mr. F. W. Perkins, of the United States Coast Survey.

The telescope employed by Assistant A. T. Mosman was reconnoitering-telescope No. 14,

United States Coast Survey, having an aperture of 3 inches, a focal length of 34 inches, and an amplifying-power of 40. It was placed just outside the observatory, at its southwest corner, in order to be protected from the northeast wind, which was blowing in puffs a short time before the commencement of the eclipse. Mr. Mosman recorded his own time, using sidereal chronometer Hutton No. 207.

The telescopes were fitted with eye-pieces for direct vision, and provided with diaphragms in which the circle was divided into octants for the approximate determination of positions of contacts and of spots on the sun. The time was obtained by transits taken on the evenings of the 6th and 7th of August.

About an hour previous to the commencement of the eclipse, the different groups of spots on the sun were plotted on large pasteboard circles divided into octants, and were then lettered so as to secure identity in designation when noting the times of their immersion and emersion. Each observer was provided with one of these circles on which to sketch and record the position and appearance of the different phenomena observed. (See Plate No. 25, Fig. 2.)

During the entire partial eclipse the sun shone with great splendor, so much so that it was necessary to use the darkest screen-glass, which, in my case, was of a deep-red color. Just before the last contact, however, when the rays appeared to be fainter, a lighter shade of red was substituted. During totality the screen was removed.

$4^h\,20^m$.—At this time cumuli clouds, lying principally along the horizon, covered about three-tenths of the sky. The wind was east-northeast, in puffs of moderate strength, say from 1 to 4. The atmosphere was remarkably clear and steady; the trees on the summits of the Alleghany Mountains, lying sixteen miles to the southeast, being readily distinguished by the bare eye.

Shortly after the commencement of the eclipse the wind died away entirely and the clouds disappeared, and the atmosphere continued until sunset unusually transparent and steady, reminding me of that of California.

The following table will show the computed and observed times of the four contacts:

Latitude of observatory	$36^\circ\,35'\,49''.10 \pm 0''.20$
Longitude of observatory west of Washington	$20^m\,32^s.77 \pm 0^s.15$
Longitude of west transit of Washington Observatory west of Greenwich.	$5^h\,08^m\,12^s.13 \pm 0^s.23$
Longitude of Bristol eclipse-station west of Greenwich	$5^h\,28^m\,44^s.90 \pm 0^s.28$
August 6.—Error of mean-time chronometer No. 215, at $10^h.1$..........	$+5^h\,17^m\,54^s.99$
August 7.—Error of mean-time chronometor No. 215, at $8^h.3$..........	$+5^h\,17^m\,52^s.26$

Contacts.	Observed time by chronometer.	Chronometer fast of Bristol mean time.	Bristol mean time of contact.	Computed time of contact.	Difference.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.	s.
First outer....	10 01 45.3	5 17 52.7	4 43 52.6	4 43 36.1	+16.5
First inner....	10 59 13.7	52.6	5 41 21.1	5 41 12.3	+ 8.8
Second inner..	11 01 45.9	52.6	5 43 53.3	5 43 45.5	+ 7.8
Second outer..	11 54 32.5	52.5	6 36 40.0	6 36 36.8	+ 3.2

The computed times given above were deduced from the results of the final computations of the observations for latitude and longitude. These results show that the position of the observatory was about four miles to the northward of the central line of the eclipse as projected according to the data supplied by the "Supplement to the American Ephemeris."

$4^h\,43^m\,52^s.6$.—Not the slightest sign of the presence or approach of the moon was observed before the contact took place. This may have been due, however, to the dark screen-glass employed. Nor was the sharp line of the sun's limb in any manner affected by the approach of the moon, or at the time of contact. Looking intently at the position-angle computed for the contact, the slightest possible change was observed to be taking place at a point in the sun's outline, and the time called, though I was uncertain at the moment whether I was correct or not. In two

seconds after, however, the black line defining the moon's edge had made sensible progress, and continued to advance across the sun's disk without the slightest change or agitation in the outline of the moon or of the apparently adjoining parts of the sun.

Table showing the times of immersion of the solar spots.

Spots, lettered, see plan of.	Time by chronometer.			Chronometer fast.			Bristol mean time.		
	h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
a, penumbra, west line of	10	24	19.0	5	17	52.7	5	06	26.3
a, nucleus, west edge of		24	39.4			52.7		06	46.7
a, nucleus, east edge of		25	11.8			52.7		07	19.1
a, penumbra, east line of		25	34.7			52.7		07	42.0
b, center of		40	50.7			52.6		22	58.1
c, center of		43	33.3			52.6		25	40.7
f, center of		42	47.4			52.6		24	54.8
g, center of		45	00.6			52.6		27	08.0
h, center of		45	23.5			52.6		27	30.9
de, center of		57	22.2			52.6		39	29.6

The following notes were made by me during the intervals between the immersion of the spots:

$4^h\ 56^m$.—Five perceptible elevations, or irregularities, on the moon's edge, situated just below the center of the arc; closely watched and found to be steady, and to retain their relative positions.

$5^h\ 00^m$.—Cusps clearly defined.

$5^h\ 08^m$.—The limb of moon projected on the sun's disk, slightly rolling, and rendering indefinite the elevations previously observed.

$5^h\ 10^m$.—Cusps sharply defined.

$5^h\ 11^m$.—Sun's rays becoming soft and mild.

$5^h\ 12^m$.—An apparent purplish tint around the edge of the moon projected on the sun, giving the appearance of its being shaded off to represent a sphere.

$5^h\ 14^m$.—The rolling or tremulousness of the limb of the moon increasing, and that of the outline of the sun commenced.

$5^h\ 16^m$.—The sun's rays like those in winter.

$5^h\ 17^m$.—Cusps undisturbed, except by the slight rolling or wavy motion, like that caused by the effect of radiated heat on the outline of a smooth bare hill, but in a very mild degree.

$5^h\ 27^m$.—Cusps sharply and clearly defined. Long shadows are cast. The summit of the Alleghanies appearing as when lit up by the last rays of the setting sun.

$5^h\ 30^m$.—Cusps very sharp and only slightly affected by rolling.

$5^h\ 31^m$.—Cusps as sharp as needles, and appearing to clasp the moon as if it were the smaller disk. At no time, so far, has the moon been seen projected beyond the sun.

$5^h\ 32^m$.—Light fading rapidly away.

$5^h\ 39^m\ 13^s.4$.—A cold dark shadow passed over the observatory, very distinctly marked. The time was called as I felt it.

$5^h\ 40^m\ 32^s.4$.—Another shadow and a much colder one bounded by; and although I was somewhat protected by the observatory, it appeared to strike me bluntly—forcibly, rather than to steal softly, quietly by. There was not a breath of air stirring.

$5^h\ 41^m\ 02^s$.—Mr. Perkins noted and recorded a third shadow, though less distinctly marked, as if they were passing in waves.

Thomas D. Walthall, esq., an intelligent gentleman residing at Bristol, and greatly interested on the subject of the eclipse, had undertaken, at my request, to note carefully the interval of time between the passage of the dark shadow over the hill, and its arrival, if perceptible, on the summit of the Alleghanies. He reported that he felt the shadow as it passed, and noted 16 seconds of time before its effect was visible on the mountains lying east-southeast, and distant 18 miles.

Just previous to totality, and when the crescent was dwindling to a mere thread, I raised, for

an instant, a marine-glass lying by my side and pointed it to the sun, but the light was even then too strong to allow of its use without a screen.

$5^h\ 41^m\ 21^s.1$.—The first inner contact was made and timed with clearness and precision, there being apparently no disturbing or exaggerating causes to affect the outlines of either the moon or the sun. Their limbs were defined with the utmost clearness to the very moment when the last ray was extinguished.

So soon as the time was called, the marine-glass was again raised and a hurried view taken of the corona; but on catching sight of the solar clouds, the screen-glass was instantly removed from the telescope, and the time of totality devoted entirely to the protuberances. (See Plate No. 25, Figs. 3, 4, 5.)

The corona appeared to be a broad circular band of silver-colored light, with an inner brighter rim, and with rays extending from different points, but very irregular in length and profusion. By far the longest rays were visible about 48° to the left of the vertex, or where the sun disappeared, and their length was estimated at the diameter of the moon. The rays on the opposite side of the circle were the next longest, being about half the length of the first mentioned. The lower left-hand quadrant appeared to be comparatively bare.

At the first glance through the telescope, the large cloud marked C, about 180° from the vertex, attracted attention, and then A and B; the two or three to the right appearing to be quite small in proportion. The position, shape, and dimensions of A, B, and C were determined as well as the means at my disposal would allow, and then of D and E; and it was while fixing the position of the last that the emersion ($5^h\ 43^m\ 53^s.3$) was announced by a sudden increase of light, and then a flash, as if, before the sun was actually uncovered, a highly luminous body was exposed, sending a flood of light about half a second in advance of the sun's rays.

The protuberances were of a pink color, varying in shade, and marked, with the exception of D, by smooth, rounded, and definite outlines. None were observed on the upper half of the circle, or above a diameter drawn parallel with the horizon. A and B, when first seen, were found to be decreasing in size, while C, and especially D and E, were increasing and assuming their true form and size just as they were extinguished by the re-appearance of the sun. There were other elevations of the same character, but very low or close to the dark circumference, presenting the appearance of a broken red line between D and E, which became visible just as the emersion took place. Portuberance C had two shades of pink, and appeared to be rolled up in itself. It was readily seen with the naked eye. The stem of D, I thought at one time was separated from the apparent dark edge of the moon, but of this I am not certain.

There was no agitation of or break in the moon's or the sun's limb, either before, at, or after the second inner contact. Both retained their respective outlines as distinct and unbroken as during the partial eclipse.

During totality a lantern was required to read the chronometer. The return of light was gradual and without the distinct waves with which the darkness came.

The times of emersion of the solar spots were not obtained with the same precision as those of the immersions. Each spot had to be clearly recognized before the time could be called, and before some of them could be so recognized they had been uncovered from one to five seconds. This correction was noted in each case at the time and applied to the times called and recorded, and was obtained by counting the seconds while the spot apparently moved over the distance it should have retrograded during the same time to have been fairly bisected by the dark line of the moon's limb. The called times of emersion thus corrected are not believed, in any one of those cases, to be over a second in error.

Table showing the times of emersion of solar spots.

Spots, lettered, see diagram.	Time by chronometer.	Chronometer fast.	Bristol mean time.
	h. m. s.	h. m. s.	h. m. s.
a, nucleus, center of	11 14 19.5	5 17 52.5	5 56 27.0
f, center of	32 36.8	52.5	6 14 44.3
g, center of	34 45.5	52.5	6 16 53.0
b, center of	36 46.0	52.5	6 18 53.5
*b*¹, center of	37 47.5	52.5	6 19 55.0
de, north end of	50 06.4	52.4	6 32 14.0
de, south end of	50 31.0	52.4	6 32 38.6

The following memoranda were made at the times stated:

$5^h\ 52^m$.—Cusps sharply defined, as during progress of emersion.

$5^h\ 59^m$.—The moon's limb projected on the disk of the sun, slightly rolling toward the cusps, while quiet and steady in the center of the arc.

$6^h\ 30^m\ 30^s$.—A low but decided elevation observable on the moon's limb, under the upper cusp of the sun, close to the point of the cusp; watched, and no change, and it was not affected by the slight rolling of the moon's outline.

There was no distortion of the cusps at any time during the eclipse, not even when the sun was close to the horizon; nor was there any agitation of the outlines of the sun or moon until within a few seconds of the last contact. This agitation, however, was not at that time sufficient to render their outlines indefinite.

$6^h\ 36^m\ 40^s$.—Just as the moon separated from the sun, that part of the limb of the sun where the separation took place appeared to be considerably broken; small pieces of the dark moon, like a broken black line, remaining along the crumbling or dissolving edge of the sun, and presenting the appearance of dark and bright spots being interwoven, or intermixed, and so distinct was this black, broken line that I began to doubt whether the separation had been completed, and so again called the time ($6^h\ 36^m\ 50^s.6$), when they disappeared.

The sun's limb was then watched, and although the black spots had gone, the crumbling appearance of the sun's limb at the locality referred to continued, and the time ($6^h\ 37^m\ 40^s.5$) was again called when the outline had been entirely restored. The sun was then settling in the horizon. There was no phenomenon at all resembling this, the Baily beads, at any other time.

The report of Assistant A. T. Mosman is hereto annexed. In the two following tables the times of contacts, immersions, and emersions, respectively determined by Assistant Mosman and myself, are brought together.

Contacts.	According to R. D. C.	According to A. T. M.
	h. m. s.	h. m. s.
First outer contact, eclipse begins	4 43 52.6	4 43 52.9
First inner contact, totality commenced	5 41 21.1	5 41 21.4
Second inner contact, totality ended	5 43 53.3	5 43 53.2
Second outer contact, eclipse ended	6 36 40.0	6 36 38.2

	m. s.
Duration of totality, according to R. D. C	2 32.2
Duration of totality, according to A. T. M	2 31.8
Duration of totality, computed	2 33.2

Spots, &c.	Times of immersion.		Times of emersion.	
	R. D. C.	A. T. M.	R. D. C.	A. T. M.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.
a^1		5 05 38.2		
a^2				5 56 54.3
a^3		5 06 33.5		
a, west line of penumbra	5 06 26.3			
a, nucleus, west edge	5 06 46.7			
a, nucleus, east edge	5 07 19.1			
a, east line of penumbra	5 07 42.0			
a, shadow		5 06 36.0		
a, center of		*5 07 35.9	5 56 27.0	5 56 23.5
b	5 22 58.1	5 22 54.0	6 18 53.5	6 18 57.1
b^1		5 24 20.6	6 19 55.	*6 20 04.0
f	5 24 54.8	5 24 54.5	6 14 44.3	6 14 45.8
c	5 25 40.7	5 25 40.3		6 21 18.3
g	5 27 08.0	5 27 09.7	6 16 53.	6 16 52.0
h	5 27 30.9			
de	5 39 29.6	5 39 27.1		
d, north end			6 32 13.9	6 32 13.0
e, south end			6 32 38.5	6 32 43.9

* Marked *bad* in the report of Assistant Mosman.

In the report of F. W. Perkins, esq., aid, United States Coast Survey, he states that—

"A few minutes before the second contact the cattle commenced coming home; I could hear the fowls arranging themselves on the roosts in the neighboring trees, and, when the extreme darkness of totality fell upon us, the crickets commenced to chirp. The air grew perceptibly cooler, adding to the sensation of awe and admiration which so uncommon a phenomenon naturally produced.

"Mercury, Venus, and Saturn were visible, but I looked in vain for stars in any of the northern constellations.

"To the naked eye, and through a marine-glass used without shades, the corona was of a white light, and the protuberances of an intense white light, and clearly visible to the naked eye. When a very light-red shade was used with the marine-glass, the protuberances appeared of a yellowish white color.

"After totality the light seemed to re-appear much more rapidly than it had disappeared, the lamps used in reading the chronometer being dispensed with almost immediately after the third contact."

Charles I. Allen, esq., of Philadelphia, who traveled to Bristol for the purpose of observing the eclipse, reports:

"Of the rose-colored protuberances, the most distinct was directly opposite the vertex; it continued throughout the period of totality, and was visible to the naked eye. A faint light of a rose color, in the shape of a cone, extended from it toward the center of the moon's disk.

"A rosy protuberance on the left or south edge, about 90° from the vertex, appeared at the beginning of totality, but soon disappeared. On the north or right edge, 90° from the vertex, a protuberance similar to the two others appeared near the end of totality; also a long forked protuberance like two streamers, about 140° from the vertex. The two last were connected, just before the re-appearance of the sun, by a row of beautiful rose-colored beads."

In the preceding report I have confined myself to a mere statement of facts and description of the phenomena as they appeared to me, deeming any discussion of theories or conclusions by any separate observer to be both inappropriate and unsafe until all the proof and evidence collected under your direction shall be brought together, criticised, and compared.

I am, respectfully, yours,

RICHARD D. CUTTS.

Professor BENJAMIN PEIRCE,

Superintendent United States Coast Survey.

BRISTOL, TENNESSEE, *August* 9, 1869.

DEAR SIR: I have the honor to submit the following report of my observations of the solar eclipse of the 7th of August. The weather, at 4^h 30^m p. m., was partially cloudy, with flying cumuli clouds, the sky being 0.3 covered. Wind east-northeast, four in strength (on a scale of 10). Atmosphere very clear and steady.

The moon's border was not seen before the first contact, nor was there any agitation of the sun's limb in the region of the contact. Very slight irregularities, which looked like mountains, were noticed on the moon's edge which was projected on the sun, as the eclipse advanced.

The moon's edge began to appear tremulous at 14^h 17^m sidereal time, or at 5^h 12^m mean time. No spots were observed on the moon. No bright bands and no illumination of the moon's disk were seen. The cusps appeared very sharp and well-defined throughout, with no distortions. The sun's edge began to be tremulous at 14^h 35^m sidereal time, or at 5^h 30^m mean time.

No projection of the moon beyond the sun, and, before totality no rapid changes of the crescent, were seen; and the time of the first inner contact or beginning of the total obscuration was very well marked, quite sharply defined, and very steady. The advance of the dark shadow was not observed by me.

During totality, solar clouds were seen (see sketch), but no corona (probably because out of the field of my telescope), and no clouds till the sun had disappeared. The two clouds, seen near the point where the sun disappeared were long, pencil-like rays; the others had the appearance of ordinary cumuli clouds; the color of all was a yellowish white, and they appeared stationary and very steady during the whole time of obscuration, and disappeared the instant the sun re-appeared. (See Plate No. 25, Fig. 6.)

I had no time to examine the space between Mercury and the sun for the supposed planet, and I saw no stars except Venus, as my attention was almost wholly directed to my telescope, watching, as I was, for the instant of the sun's re-appearance. An increased brightness of the sun's limb was noticed about five seconds before emersion, but no flashes or bright rays. No projection of the moon beyond the sun was seen as the moon receded, and the edges of both the sun and moon were remarkably steady, and no distortion of either of the cusps was seen. The moon seemed of a uniform blackness as it receded; very slight irregularities, as on advancing, were noticed, but no illumination of its disk and no spots on its surface.

The moon was not seen after leaving the sun, but the sun's edge in the region of the last contact remained irregular for over a minute after the moon had disappeared.

The following are the times of the different contacts, and the immersion and emersion of the spots, observed by me with sidereal chronometer Hutton 207, which was slow $3^s.7$, and in the next column are the observations in mean time. The rate of chronometer 207 was losing $0^s.04$ per hour.

The telescope used by me was reconnoitering-telescope No. 14, United States Coast Survey; aperture, 3 inches; focal length, 2 feet 10 inches.

Yours, respectfully,

A. T. MOSMAN,
Assistant, Coast Survey.

General R. D. CUTTS,
Assistant, United States Coast Survey.

Approximate longitude from Washington .... $+20^m$ 33^s
Approximate latitude .... 36° 35′ 49″

	Time by sidereal chrnm. No. 207.			Bristol mean time.		
	h.	*m.*	*s.*	*h.*	*m.*	*s.*
First outer contact	13	49	40.5	4	43	52.9
First inner contact	14	47	18.6	5	41	21.4
Second inner contact	14	49	50.8	5	43	53.2
Second outer contact	15	42	44.5	6	36	38.2

Solar spots.

Immersion.			Emersion.		
	By 207.	Mean time.		By 207.	Mean time.
	h. m. s.	*h. m. s.*		*h. m. s.*	*h. m. s.*
a^1	14 11 29.5	5 5 38.2	a^1		
a^2			a^2	15 2 51.0	5 56 54.3
a^3	12 25.0	5 6 33.5	a^3		
(a) shadow.	12 27.5	6 36.0			
a	13 27.5?	7 35.9?	a	15 2 23.5	56 23.5
b	28 48.1	22 54.0	b	25 0.5	6 18 57.1
b^1	30 15.0	24 20.6	b^1	26 7.5? bad.	20 4.0? bad.
f	30 49.0	24 54.5	f	20 48.5	14 45.8
c	31 34.9	25 40.3	c	27 22.0	21 18.3
g	33 4.5	27 9.7	g	22 55.0	16 52.0
d	45 24.0	39 27.1	d	38 18.5	32 13.0
e			e	15 38 49.5	32 43.9

OBSERVATIONS AT SHELBYVILLE, KENTUCKY, AND AT OTHER STATIONS IN THE VICINITY.

CAMBRIDGE, *June* 1, 1871.

SIR: In accordance with your instructions of July 7, 1869, I arranged for the observations of the total eclipse of August 7, to be made in Kentucky by officers of the United States Coast Survey, in co-operation with the expedition sent out from the observatory of Harvard College.

The stations selected were Shelbyville and Bardstown, near the central line; Falmouth, near the northern limit of the shadow; and Oakland, near the southern limit.

Shelbyville was made the principal station on account of the advantages it offered in its college buildings and grounds and its fine Munich telescope, which were generously placed at our service by the proper authorities.

It was thought best to have another station somewhat nearer the central line than Shelbyville, for an additional chance of clear weather, and for the reason that the general appearance of the eclipse might be different at different stations not far distant from each other. Bardstown seemed to me to satisfy these conditions.

Observations for precision, including latitude, longitude, and time, were made by Mr. Dean and Mr. Blake, at Shelbyville, and their reports have been forwarded to you. The photographic observations were made at this station. In that department of the work I was assisted by Mr. Whipple, Mr. George D. Clark, Mr. John Pendergrast, and also by Mr. Williams, a photographer of Shelbyville, who kindly offered his services. The instrument employed was the small equatorial of Harvard College observatory, which I had fitted up for this purpose. It has a clear aperture of 5½ inches, and a focal length of about 7½ feet; and it is provided with an excellent driving-clock. In making preparations for the use of photography in these observations, I decided to take the pictures of the sun in the principal focus of the object-glass. I rejected the method of enlarging the image with an eye-piece, adopted by Mr. De la Rue, in Spain, in 1860, and by American astronomers who were preparing to photograph the eclipse of 1869, because, my main object being to secure a good picture of the corona, I did not think it expedient to enfeeble the light by enlarging the image. Another reason in favor of this method is that the distortion caused by the enlargement is avoided, and the pictures can be measured more satisfactorily with a micrometer. The camera was fitted with a slide near the image, for instantaneous exposure in taking the partial phases. During totality the slide was removed and the exposure was made by uncovering the object-glass.

The results were very satisfactory. We succeeded in obtaining about eighty photographs during the eclipse, seven of which were taken during totality. One of these, with an exposure of forty seconds, gives a most satisfactory picture of the corona. I immediately recognized in this the fact that the corona was less in extent near the extremities of the sun's axis, and largest in the line of the equator. I have reason to think that this picture gives nearly all of the corona which can with certainty be considered as belonging to the sun. Fainter light beyond the limits of this picture was seen by observers at this station, whose reports have been forwarded to you; but this light may be terrestrial, and is, no doubt, partially so.

My object in taking so many pictures of the partial phases was to ascertain the degree of accuracy with which they could be measured when taken in this way. I hoped to obtain valuable information from them in regard to the use of photography in observations of the approaching transit of Venus. I intended to make the measures in such a way that the distances between the centers of the sun and moon, or of the sun and Venus, would be obtained free from the effects of photographic irradiation. With your authority, I have since directed the construction of a micrometer by Messrs. Alvan Clark & Sons for this purpose, and many measures have been made with it, which indicate the possibility of an accuracy in this method of observation greater even than I had anticipated. The micrometer has two very accurate screws and a position-circle. The method of measuring was to find as accurately as convenient the center of the sun or of the moon, and measure from this center radii, at suitable intervals, to both curves. The error of centering and the eccentricity of the curves were then found by the method of least squares.

When this method of observation is applied to eclipses or to the transit of Venus, the position-angles may be determined by finding the positions of sun-spots with another telescope. If the plates are carefully prepared with straight edges, the position-angles for the total phase may be determined by the positions of the cusps.

Some of the results of measures of these photographs, together with engravings of the eclipse, and also a description, with engravings, of the micrometer, will be found in my report to be published in the Annals of the Observatory of Harvard College.

Soon after the eclipse I employed Messrs. Alvan Clark & Sons to make an object-lens of four inches aperture and forty feet focal length. Although this is a simple lens of plate-glass, without compensation for color, excellent pictures of the sun have been taken with it. They are about four inches in diameter, and can be measured with the micrometer above mentioned. I expect in this way to be able to measure the motions of sun-spots with a decree of accuracy that has not hitherto been attained.

For spectroscopic observations, an excellent equatorial telescope by Merz, of $9\frac{1}{2}$ feet focal length and $7\frac{1}{2}$ inches aperture, was employed, to which was attached a spectroscope of two flint-glass prisms, made by Troughton & Simms. The chromosphere was carefully examined, both before and after the eclipse. Only three lines could be seen: C, one near D, and F. During totality only the brightest protuberance on the lower limb of the sun was examined carefully. In the short time occupied in getting this, nothing was seen but a faint continuous spectrum; but since the telescope took in only a small part of the spectrum at once, nothing conclusive can be inferred from the observation as to the non-existence of bright lines in the corona.

During totality, eleven bright lines were seen. Besides the three already specified, there was a short line at or very near E. The three lines of *b* were bright and very sharp, and there were four lines above F. Although these lines were very dark on a bright ground, all of them but the three seen before the eclipse disappeared instantly on the first burst of sunlight, and the same point in the sun's disk was examined with great care after totality without finding any of the lines except those above described.

It was my intention to connect our standard break-circuit chronometer with the line of telegraph, so that its beats might be heard at any station on the line, and that the telegraph-clerks or other observers might register the times of contacts upon the fillets of the Morse registers at all telegraph-stations within the shadow; but as this was not possible, there being no line of telegraph through Shelbyville, I placed a second-pendulum in connection with the line at Oakland, and, by the co-operation of the assistants on the line, the duration of the total phase was registered at several stations, the results of which observations will be found in Mr. Dean's report.

The observations at Falmouth were placed in charge of Mr. Arthur Searle, assistant at the observatory of Harvard College. Those at Oakland were under the direction of Professor S. P. Langley, and those at Bardstown were conducted by Mr. Charles S. Peirce. For the details of what was done by them, reference is made to their own reports, which follow.

Very respectfully,

JOSEPH WINLOCK.

Professor BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

CAMBRIDGE, *August* 20, 1869.

SIR: In accordance with your instructions I transmit to you the following account of the observations made by me on the solar eclipse of August 7. The station which you selected for me was Bardstown, Kentucky, a little southwest of the central line of the eclipse.

I was furnished with an elegant equatorial telescope of four inches clear aperture, and five feet focal length. Upon opposite sides of the tube of this telescope, and parallel to it, were attached two brass rods at the eye-end of the tube, and reaching about a foot beyond it. Upon these rods was fixed the spectroscope, and in such a manner that the slit was plainly visible. I found this arrangement of yours all that could be desired. With it I had little need of a finder. Pieces of white paper were pasted upon the brass-work of the slit to receive the image of the sun, which, during totality, could not well have been seen upon the polished brass. There was some danger of detaching this paper in opening and closing the slit, and I therefore wished to change the width of the slit as few times as possible during totality. The spectroscope attached to my telescope contained a single flint-glass prism and a three-prism direct-vision spectroscope screwed in in place of its telescope. There were no means of measuring the positions of the lines. In order to bring different parts of the spectrum into view it was necessary to unscrew a binding-screw, which then left the somewhat heavy arm which carried the direct-vision spectroscope entirely loose, and then to move this arm with the hand and tighten up the screw. When this was done the arm would fall a little, and it was only by looking at the spectrum, and estimating how much the arm would fall that it was possible to set upon any part of the spectrum. During totality there might be no light in the field if the observer were to move away from a protuberance, and, therefore, no means of knowing to what part of the spectrum, if any, the arm was set. If the slit was opened to give full light, the paper pasted on it might become detached and render it impossible to set the slit on a protuberance. There was no clock-work on the telescope, and the observers were in continual apprehension of some disturbance in the crowd of mostly ignorant spectators, and therefore an attempt to move this arm was a thing to be dreaded. On the other hand, it could be so set as to afford a view of the spectrum from its red extremity up to half-way between F and G. Under the circumstances I would not venture to move it. If I had been alone, and consequently at my ease, I should have done so.

My telescope was pointed for me by Mr. N. S. Shaler, the geologist, who generously relinquished his opportunity of witnessing the sublime phenomenon undisturbed, and offered his assistance in the astronomical observations. My telescope was, therefore, managed for me with perfect skill and coolness.

Upon the morning of the 6th I set up my instrument and searched for protuberances. I found only one, which was upon the following side of the sun, and was very yellow, that is to say, the yellow line near D was relatively very bright in it. Indeed, I could not see the F line at all. On the morning of the 7th I examined the sun with greater care, and noted several protuberances (which were afterward plainly seen at totality), but none of these were as brilliant as the one which had been seen the day before continued to be; and this was now less high, extended over a larger arc on the disk of the sun, and was still more yellow than it had previously appeared.

At the instant of totality my telescope was pointed on this protuberance and my slit was rather narrow. At that instant the continuous spectrum vanished, and five lines, brilliantly colored, became visible. These were F, *b*, another dimmer and broader line, say one-fourth of the distance from *b* to D, the well-known yellow line near D and C. After observing the spectrum of this protuberance at different positions, I looked at the sun, and was pleased to find my conceptions of the shape and color of this protuberance entirely confirmed.

The same glance showed me upon the southwestern limb of the sun (where my business chiefly lay) a well-marked rose-colored protuberance. I first observed the spectrum of another red protuberance on the southern edge, and then that of the one just mentioned. I found the spectra of the red protuberances to be alike; they differed from that of the yellow one only in the relative greater brilliancy of the red, yellow, and blue lines in the former, the fainter green being especially much fainter. I have no doubt, from my previous observations, that the yellow line was also less bright in the red protuberances, but it appeared so bright that I could not perceive that it was less bright than in the yellow protuberance.

Mr. Shaler then pointed for me on the corona, and I was just opening the slit to get more light when the sun burst forth and put an end to my observations. Two seconds more, or a little more privacy, would have enabled me to get it.

During the eclipse the following miscellaneous observations were made by Mr. Shaler and me:

The protuberances were of two distinct kinds: one sort was low, long, and yellow; the other high, short, and red.

Mr. Shaler saw the disk of the sun break into beads at the moment of totality. The appearance lasted only an instant, and seemed as if it were the effect of irregularities of the limb of the moon. About a month before, Mr. Shaler had observed on the limb of the moon a serrated appearance occasioned by a range of mountains.

Mr. Shaler observed that the corona formed a quadrangle, with concave sides vertical and horizontal, the latter being the longest. He estimated its mean breadth at one and a half the diameter of the sun. He found that it did not fade gradually away, but had a sharply defined edge.

I noticed the following points in reference to colors. While the eclipse was coming on there was no change in the colors of the landscape or of people's faces, but the light had a singular theatrical effect, owing to the sharpness of the shadows. During totality, the light on the landscape was like the gray of twilight. The moon, at this time, was not black, but of a deep, dull, and somewhat purplish blue, darker than the sky. Mr. Shaler confirmed this. The sky was of a dark purplish blue. It was not lighter near the corona. The corona was quite white and not bluish. The yellow protuberances were greenish like the aurora, and intensely brilliant. The red ones had much the color of the light from hydrogen in a Geissler tube. Upon the south, and also (as Mr. Shaler says) on the north, was a salmon-colored light upon the horizon, reaching up some five degrees or more. Venus and Mercury looked as white as Vega ever looks.

Mr. Shaler says: "Little effect was visible on animated nature until the last five minutes before totality, except that the cocks all began to crow, at several points, with the sleepy crow of early morning and not the exultation of full day. The birds began to make their nesting-cries as the light rapidly waned. Cattle were evidently much alarmed, and ran, with tails up and heads erect, across the fields almost in stampede. At the close of the eclipse a hen was found, with her chickens under her wings. Four months' old chickens were seen, within ten minutes of the total eclipse, quietly feeding. They then disappeared. The crowd was placed, at the request of the observer, beyond a fence, distant about thirty feet from the telescope. At the moment of totality a hollow sound, half of fear, half of admiration, called attention to their faces, with dropped jaws and look of horror, which were turned toward the wreck of the sun. There is no doubt that exceeding fear took possession of the whole people. The many who were present slipped away quietly; the few who staid after totality seemed singularly quiet, evidently recovering from a considerable nervous shock."

All of which is respectfully submitted, &c.

CHARLES S. PEIRCE.

Professor JOSEPH WINLOCK.

Professor J. Lawrence Smith has furnished the following memorandum of his own observations:

The observations at Bardstown were limited in their character, being directed specially to spectroscopic observations. Mr. C. S. Peirce, of Cambridge, made one set of observations with the spectroscope attached to a telescope, while I made observations with the spectroscope detached. I also observed the solar thermometer, and the intensity of the chemical action of the light as measured by strips of silvered paper, exposed frequently at uniform intervals, for the spaces of one minute to the direct action of the sun, from the commencement of the eclipse to the termination of the totality. I also made barometrical measurements at different times. But as the instrument used was a pocket-aneroid, very little reliance can be placed upon them. The temperature of the direct rays of the sun was 111° Fahrenheit, and diminished rapidly during the passage of the disk of the moon across the sun, until, at the complete obscuration of the sun, the thermometer stood 10° lower than it did in the shade at the commencement of the eclipse. The chemical action of the rays of the sun diminished gradually, until the action of the sun had but little effect on the silvered paper after ten minutes. The most interesting part of my observations is, that a good single-prism spectroscope will give at least four bright rays in the protuberances, unaided by a telescope, to form a disk of the sun. The spectroscope attached to the telescope gave Mr. Peirce five lines, but I do not think that I speak too confidently in stating that five lines might have been seen by the naked spectroscope had it been better mounted for giving direction to it. The four bright lines, as nearly as I could make them out, were one in the red, in or near the line *C;* one in the orange, in or near *D;* one in the green; and one in the blue, in or near *F.*

MEMORANDUM BY ARTHUR SEARLE OF WORK DONE AT FALMOUTH, KENTUCKY, ON AUGUST 6 AND 7, 1869, WITH REFERENCE TO OBSERVATIONS OF THE SOLAR ECLIPSE.

The instruments taken to Falmouth were the Lerebours telescope from Harvard College observatory; the Dollond telescope from Saint Paul's Church, New York; a pendulum regulated to beat seconds, and provided with a break-circuit attachment; two Morse telegraphic registers and reels; three break-circuit keys; and a stop-watch. A second stop-watch, meant for the Falmouth station, was forgotten and left at Shelbyville.

My instructions were to observe personally the duration of the total phase by means of one of the Morse registers (provided the electrical apparatus could be brought into action before the eclipse), observing the disappearance of the sun with a telescope, its re-appearance with the naked eye, and not attempting any estimate of the time by ear, but confining my attention to giving the electrical signals as accurately as possible; to have an observation taken by Mr. West, the Falmouth telegraph-operator, of the duration of the total phase, with the office-register, by similar signals; and to assign work to any volunteer-observers according to my own judgment.

I reached Falmouth about 10 a. m., Falmouth time, on August 6. On inquiry, nothing could be heard of Mr. Ross, who had been thought likely to be found in Falmouth, and available as one observer; but two gentlemen, Captain W. C. Crozer and Captain W. E. Arnold, both civil engineers, kindly volunteered their services, which proved of very great value.

Mr. West had received instructions with respect to the proposed observations, and furnished me with every facility for carrying out the plans which had been formed. The short interval remaining before the eclipse made it necessary that the station for the observations should be placed near the telegraph-office, in order that Mr. West might have time to make the arrangements required without neglecting his regular business. Leave was therefore at once requested and obtained from the owner of the field on the opposite side of the railroad to erect a small stand

there. The stand was put up in the course of the afternoon, an upright case being attached to one end of it for the pendulum, which required protection from the wind and weather as well as from interference by bystanders. The boards inclosing it on one side were fastened by screws, so that it was easily got at when desired. It was set up and partially adjusted before night, but, as the workman who was to make a loop in the telegraph-line could not do so till morning, it was taken down and replaced in its box.

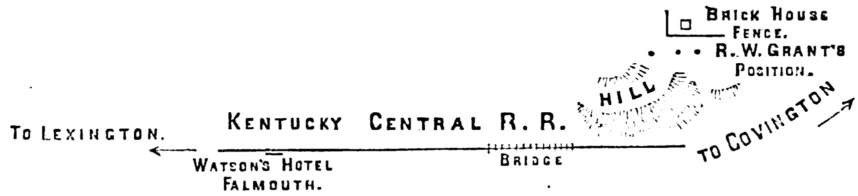
Mr. West received the materials for a local battery toward night, and during the evening he contrived the connections required for working the three registers with the pendulum and break-circuit keys, making a diagram of the positions of the wires, so as to set them up readily the next day.

Early on August 7, a loop in the telegraph-line was brought to the stand; but Mr. West's regular occupations prevented him from getting the local battery and wire connections set up until near noon; and then the control of the line could not be had for the purpose of experimenting with the pendulum. Shortly before the eclipse, the pendulum was adjusted so far as possible. Its break seemed somewhat longer than desirable, but further experiments were interrupted by messages upon the line, and soon after by the pendulum from Oakland, which was found to work satisfactorily. Mr. West did not succeed in getting control of the line again for any further adjustment of the Falmouth pendulum, which, as it happened, was not needed, the Oakland pendulum continuing to break the circuit regularly.

Meanwhile, Messrs. Crozer & Arnold had collected several other gentlemen willing to assist in the observations. The telescopes had been placed on the stand early in the afternoon, and the registers and keys were in position, and were found to work promptly. Captain Crozer undertook to use one of the telescopes in connection with the third register. To prevent irregularities in the running of the registers, I had requested Mr. West to provide an assistant for each to keep them working properly; and he assigned this duty to his two subordinates, who were used to the management of telegraphic apparatus. Mr. West managed his own register himself, and observed without a telescope. I took the Lerebours glass, and gave Captain Crozer the Dollond.

By way of practice, Captain Crozer and Mr. West several times took the interval between signals, given as described hereafter, with their keys and registers, and found no difficulty, on any occasion, in obtaining legible and closely agreeing results. But the observation of the total phase of the eclipse by this method proved almost a complete failure. Mr. West's register seems to have run well, but no signal for the re-appearance of the sun can be found on the fillet. The signal may perhaps be coincident with one of the breaks of the pendulum. Captain Crozer's register ran very irregularly, as the fillets seem to show, and, although it is probable that all his signals are recorded, it is doubtful whether their places can be clearly ascertained. He thinks he gave one tap only for the disappearance of the sun, and for its re-appearance (observed with the naked eye) two taps, the second of which is to be preferred. The fillet of my own register was broken, the register stopped, and not started again, several seconds before the total phase began; and my taps, which I think were given as accurately as any I am in the habit of giving on the chronograph-key, were not recorded. I did not discover this, of course, until after the total phase was over, when, on inquiry for the electrical records, the facts just stated appeared. We must, therefore, depend chiefly upon the stop-watch, and upon a tally observation by Captain Arnold.

The stop-watch had been placed in charge of Mr. R. W. Grant, whom I directed to station himself upon a hill toward Covington, just beyond the railroad-bridge, both to obtain an observation nearer the border of the shadow, and to lessen the chance of confusion and of interference with the observer by bystanders. Before leaving the stand, Mr. Grant repeatedly took the interval between signals, which I gave him from some distance, with my eye upon my own watch. His results uniformly agreed with mine to the fifth of a second, and I believe his observation to be a very good one. Mr. W. Clarke has promised to see that the place where Mr. Grant stood is marked by a stake; but it is already indicated by the most northerly of three stumps on the hill, close to which he stood. This stump may perhaps be two rods from the fence near it.

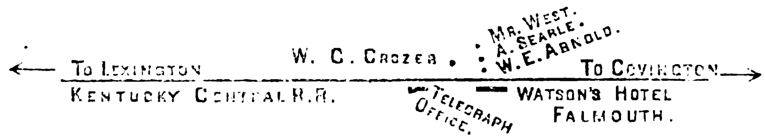


The duration of the total phase at Mr. Grant's station was forty-one and six-tenths seconds as indicated by the stop-watch. This observation is confirmed by Judge Hudnall, who took the time by his own watch at the same station, and found it to be forty-one seconds, and some fraction (he thought a small one) of another second.

I was fortunate enough to obtain the aid of two gentlemen, Messrs. B. Johnson and D. Yelton, who consented to give up seeing the total phase of the eclipse for the purpose of recording by tally an observation undertaken by Captain Arnold, at the stand. The preliminary drill for this observation was as follows: The tallymen were seated facing Captain Arnold, and at some distance behind them signals were given by Mr. Scott, by smartly raising one piece of pasteboard from behind another. Captain Arnold repeated these signals to the tallymen by rapid gestures of his hand. As the telegraph-line was in use for messages when we began our experiments, I counted seconds from my watch for the tally. Both tallymen began recording at the same second, the mark for every fifth second being drawn across the four preceding marks, as usual in keeping tally, for convenience in counting. On receiving Captain Arnold's first signal, Mr. Johnson stopped his tally while Mr. Yelton went on with his, stopping at Captain Arnold's next signal, upon which Mr. Johnson resumed his tally, and continued it until the word was given to stop. The whole number of seconds counted from the watch served as a check for the accuracy of the work, which soon became correct almost every time. Meanwhile, Judge Lee and Mr. C. A. Wandelohr endeavored to estimate the fractional part of a second at which Mr. Scott gave his signals, and their results agreed well together. As soon as the Oakland pendulum could be replaced on the line, the click of the magnet was substituted for my count of seconds; Captain Crozer and Mr. West began observing and recording Mr. Scott's signals with their registers, as above stated, and I observed by eye and ear. On each trial I found that Judge Lee's and Mr. Wandelohr's estimate of fractional parts of seconds agreed well with mine; that the tally record agreed with my silent count of whole seconds; and that both the Morse registers confirmed these observations. I did not wish to fatigue the observers by too frequent a repetition of this work immediately before the total phase; and as the eclipse was already far advanced, I satisfied myself with a few repetitions of the experiment. It was unorftunate that, just as the total phase was about to begin, the train from Lexington drew up at the station, remained there during the totality, with the passengers shouting, screaming, laughing, and talking all the time, and started again as the sun re-appeared. Hearing this hubbub, I gave up my tally observation for lost; but, after learning the failure of the electrical apparatus, I was doubly pleased to find that, although Mr. Yelton, on whom the result chiefly depended, had found it very difficult to hear the magnet, and was therefore not so sure of the correctness of his work as he would otherwise have been, there was still very little doubt that, by Captain Arnold's observation, the total phase had lasted forty-five seconds. Judge Lee and Mr. Wandeohr had been unable to hear the magnet sufficiently well to estimate the fractional parts of seconds, but in any case some doubt must have existed as to this part of the observation, unless I had asked these gentlemen also to give up seeing the total phase, and to look only to Captain Arnold's signals. Captain Arnold himself has considered that it would be safest to confine his attention to giving his signals correctly, and not to attempt to estimate the fraction of a second at which he gave them. He is inclined to think, however, that the interval was nearly an exact number of seconds, and that, if not forty-five seconds exactly, it should be considered a little less rather than at all beyond that time. His observation is confirmed by one taken independently by Mr. Woodson, with his own watch, and assisted by a friend, upon a platform of the railroad-station. Mr. Woodson found the duration of the total phase to differ very little, if at all, from forty-five seconds.

I learn, also, that Mr. Knight, observing from the hotel, and that Mr. Johnson (father of our tallyman), observing from his house, somewhat southwest of the hotel, obtained the same result. But as I have not seen these gentlemen, some doubt may exist as to the accuracy of the reports given me of their observations, or of the entire independence of the observations themselves.

The positions of the principal observers are marked by stakes thus:



The stakes are from two to five feet apart. The diagram exaggerates their distances.

Mr. D. Crozer, jr., of Catawba, about four and a half miles from Falmouth, informs me that he observed the duration of the total phase at that place to be twelve seconds. His father noted the time with his own watch. Mr. Crozer promises to have a stake set at once where he stood when making this observation.

Two points are reported where the eclipse seemed just to fail of totality: one is John Johnson's house, above Antioch meeting-house, about eight miles east of Falmouth; the other is a place known to Mr. A. R. Clarke, about seven miles from Falmouth, but these observations are probably not accurate enough to be of service.

The tally record will be serviceable, not only in directly exhibiting the length of the total phase, but also in deciphering the fillets from the Morse registers; for Mr. West thinks that the three registers were all started very nearly at the same instant, and I gave the signal for the tallymen to begin their record a few seconds after directing the registers to be started. Mr. Johnson's tally comprises one hundred and eighty seconds; Mr. Yelton's two hundred and twenty-five seconds, with one additional mark, which he is certain he made after Captain Arnold's signal for the re-appearance of the sun.

An examination of the fillets, made at Cambridge, August 17, 1869, gives some little ground for the following conjectures: That Captain Crozer's register was started about five seconds before Mr. West's (or that a few marks on Captain Crozer's fillet belong to one of the previous experiments); that Mr. West's first break failed to be recorded, or coincides with a break of the pendulum; that about thirty-four seconds after Captain Crozer's first break his register began running slow, and two seconds later became almost stationary, and continued so for some three seconds; that it was then started with a jerk which caused the next three or four seconds to be recorded irregularly, and in a broken manner; that the first of the two breaks, supposed to have been given by Captain Crozer for the sun's re-appearance, was given with hesitation, and appears as two very short breaks upon the fillet; and finally, as the result of the preceding conjectures, that Mr. West's observation would make the length of the total phase only about forty-four and four-tenths seconds, and Captain Crozer's observation forty-four and six-tenths seconds. But it is doubtful whether this conjectural result deserves any further consideration.

The stop-watch used at Falmouth was compared with the east clock at Harvard College observatory, August 20, 1869, and found to gain on that clock two seconds in thirty-eight minutes. The clock gained about two-hundredths of a second in the same time, if running at its ordinary rate. The stop-watch, therefore, gains on true mean time $0^s.053$ in one minute, or $0^s.038$ in two-thirds of a minute. This rate agrees closely with that given by G. M. Searle ($0^s.03$ for the duration of the total phase as observed by the stop-watch at Falmouth) from comparisons of the same stop-watch made by him in New York before the eclipse.

The remaining observations at Falmouth were as follows: The time given is that of my watch (near New York time). Below are comparisons of this watch with chronometer Frodsham 3451, at Shelbyville, and with G. M. Searle's watch, which last was fast of Shelbyville mean time $4^m 25^s$

at $11^h 39^m$ a. m., August 5 (or $23^h 39^m$ August 4, astronomical mean time), with a losing rate of thirty-nine and one-tenth seconds for that day.

Captain Crozer used the Dollond telescope, with a power of 25, throughout the eclipse (except for the re-appearance of the sun). I used the Lerebours glass (with the same exception as already noted). Both telescopes had their apertures reduced to about three-fourths of an inch by pasteboard caps, until near the total phase. After the total phase, the cap was replaced on the Lerebours telescope, but not on the Dollond.

Eclipse began at $5^h 15^m 36^s$. (Observer, W. C. C.)

Light sensibly diminished upon landscape at $5^h 46^m$. (A. S.)

Preceding cusp suddenly blunted (soon recovering its sharpness) at $5^h 52^m 15^s$. (W. C. C.)

Preceding cusp very irregular, and even serrated or forked at the extremity, at $6^h 7^m 30^s$. (W. C. C. and A. S.)

Limb of the moon decidedly more irregular toward the preceding than toward the following cusp throughout the increase of the eclipse. (W. C. C. and A. S.)

Re-appearance of a large group of spots near the point of the sun's limb farthest from the zenith at $6^h 30^m$. (W. C. C.)

Re-appearance of two small spots, one about one-fourth of the distance from the extremity of the preceding to that of the following cusp, the other about three-fourths of the same distance, at $6^h 56^m 33^s$. (W. C. C.)

Group of spots near the following cusp toward the end of the eclipse. (W. C. C.)

Eclipse ended at $7^h 9^m 50^s$. (W. C. C. and A. S.)

Mr. C. A. Wandelohr noted the beginning of the eclipse, as apparent to the naked eye, at $5^h 16^m$; the end of the total phase at $6^h 15^m 4^s$; the end of the eclipse at $7^h 9^m 4^s$.

Judge Hudnall, at Mr. Grant's station, observed the end (?) of the total phase at $5^h 31\frac{1}{2}^m$ by his watch, which was 44^m slow of mine when compared with it at $6^h 36^m 45^s$.

Nothing was seen of "Baily's beads," I believe, by any observer; but the cusp of the sun was broken into several irregular fragments a few seconds before the total phase, according to the observations of Captain Crozer and myself.

During the total phase, no observer used a telescope. A somewhat doubtful observation of red prominences was made to the south of the principal station by Messrs. C. B. Wandelohr and P. F. Bonar, who report that they thought they saw one large prominence on the upper limb of the sun and three small ones to the left. Mrs. Arnold saw a "star" under the moon (probably the large protuberance observed there at other stations).

The corona seems to have presented much the same appearances to all observers, allowing for differences of description. It closely resembled the best published engravings of this phenomenon as I saw it, but no special peculiarities were noticed in it.

Messrs. W. W. Ireland, A. R. Clarke, W. G. Cooper, and Dr. Barbour observed for stars visible during totality; and other observers also reported on the same subject. Three small maps of stars near the sun were used. There seems to be no doubt that Mercury, Venus, and Regulus were all visible during the total phase.

Mr. W. G. Cooper describes Regulus as very brilliant, in a written report which I received from him; but the star may have been easily confounded with Venus. Arcturus, Vega, and Saturn were distinctly seen by various observers.

Mrs. Murphy saw two meteors during the total phase. The first was traced from a point near the meridian and not far from the zenith toward the southeast; the course of the second was from the northwestern to the southwestern part of the sky.

Mrs. Arnold reports the usual phenomenon of poultry coming to roost during the eclipse.

The diminution of light was not at any time very great. A lantern had been provided for the tallymen, but I believe no use was made of it, and the darkness seemed only about equal to what is usual a minute or two after a clear sunset.

The shadow of the moon was noticed, I understand, by some observers toward the north, but does not seem to have been regarded as a striking phenomenon. (The driver of the stage between Eminence and Shelbyville says that it appeared to him no more distinct or dark than an ordinary cloud-shadow.)

Mr. W. G. Cooper describes the atmospheric effects and the tints of the landscape as presenting a very beautiful and interesting spectacle.

Mrs. Arnold compared the appearance of the landscape, after the total phase, to that presenting itself to a spectator just coming out of the Mammoth Cave.

The whole day was unusually bright and clear for the season.

Results of observations.

Duration of total phase at Falmouth station .... 45 seconds.
Duration of total phase on hill north of Falmouth .... 41.6 seconds.
Duration of total phase at Catawba .... 12.0 seconds.

Beginning of eclipse at Falmouth station, by watch of A. Searle .... $5^h\ 15^m\ 36^s$
End of total phase at Falmouth station, same watch .... $6^h\ 15^m\ 4^s$
End of eclipse at Falmouth station, same watch .... $7^h\ 9^m\ 50^s$

Baily's beads not seen. Prominences visible to the naked eye on the upper and lower limbs of the sun (and perhaps on the southern side).

Mercury, Venus, Regulus, Arcturus, Vega, and Saturn visible during the total phase.

Two meteors seen during the total phase; their point of divergence probably in the northwest.

Watch comparisons.

	Chronometer Frodsham 3451.	Watch of G. M. Searle.
1869.	*h. m. s.*	*h. m. s.*
August 5	9 28 30	11 43 46.5
August 7	8 32 30	10 38 54.5
August 8	7 00 00	9 2 8.0
August 9	9 24 00	11 18 6.0

	Chronometer Frodsham 3451.	Watch of A. Searle.
1869.	*h. m. s.*	*h. m. s.*
August 5	11 16 0	2 12 1

	Watch of G. M. Searle.	Watch of A. Searle.
1869.	*h. m. s.*	*h. m. s.*
August 5	2 20 0	3 1 13
August 5	3 52 0	4 33 19.8
August 5	18 57 53	19 40 50.2
August 6	4 49 3.3	-5 22 50.0

REPORT BY PROFESSOR S. P. LANGLEY OF OBSERVATIONS AT OAKLAND, KENTUCKY.

DEAR SIR: On the 3d of August, I left Louisville, with Mr. Graham Wilder, arriving at Oakland the same day. It is a station on the Louisville and Nashville road, with only one or two houses in the vicinity, and no telegraph-office within ten miles.

No buildings being accessible near the track, I had two small sheds, each about 8 feet by 10, moved into the field bordering the railroad, to a site which commanded a fair view westward. No entirely satisfactory site was procurable. We made these sheds water-tight as far as we could, and by Thursday evening (the 5th) had mounted in them the instruments.

These consisted of a Coast Survey zenith-telescope, loaned by Mr. Dean (which I mounted, but unfortunately could not use, both the nights of the 5th and 6th being rainy;) of a chronograph and a telescope of about 3-inch aperture, which I brought from Pittsburgh; of a Morse register and a pendulum beating sidereal seconds, with a stop-watch; and the necessary batteries, &c.

Mr. Wilder brought with him a good pocket-chronometer made by Reardon, of London, but we were without the local time.

All these, except the zenith-telescope, were placed in the shed looking west, the site of which is carefully marked and described in a memorandum placed in the charge of the Coast Survey.

The telegraph-operator, Mr. De Brie, arrived Friday afternoon, and connected our station with the main lines.

The spare time was occupied in practicing the observers, by noting the times between various signals made at irregular intervals for the purpose, and in trying to procure and instruct amateur observers in noting times by their watches, the latter with poor success.

On the afternoon of the 7th, our isolated station was the resort of all the inhabitants of the adjoining country, white and black, who crowded around the sheds, interrupted the view, and proved a great annoyance.

A special train from Bowling Green brought some hundred more, who arrived upon the ground and within the inclosure just before totality, very opportunely, with a brass band.

Our arrangement was as follows: The pendulum broke the circuit on the chonograph, Morse register, and main line. I observed immediately in front of the shed, using the telescope of say 3-inch aperture, and a terrestrial eye-piece of about 30 diameters magnifying-power, recording on the chronograph. Mr. Wilder, near me, used a good field-glass and the Morse register. Mr. De Brie, naked eye and register; the latter being instructed to count the beats audibly, between internal contacts, as a safeguard in case the register failed.

We were expecting about thirty seconds' totality, from the presumed latitude of Oakland. The phenomenon of Baily's beads was so unusually protracted as to prepare me for the conclusion that we were much nearer the edge than I had expected, but the almost instantaneous re-appearance of the light took me by surprise.

All the records of our observations were placed in charge of Mr. Dean, by me, when I left Louisville, and I take the following figures from memory:

S. P. Langley (from chronograph), duration of totality	$1^s.75$
G. Wilder (from Morse fillet), duration of totality	$2^s.05$
De Brie (from Morse fillet), duration of totality (conjecture)	$1^s.$

I saw the light dwindle to a star-like speck, which hung on the limb about a second after the rest went out (and which was due, as I conjecture, from its distinctive appearance to a lunar cleft); as this was disappearing, I struck the key and removed my eye from the telescope, but saw an almost simultaneous burst of light from the sun, and signaled again after looking once more through the instrument. I have no doubt that in my case the $1^s.75$ is a sufficiently large estimate.

Mr. Wilder, who, like myself, was expecting a longer interval, is satisfied that his $2^s.05$ is too large. Mr. De Brie struck once coincidentally with Mr. Wilder, and, as he says, had no time to strike again before the sun re-appeared.

If, under these circumstances, it be permitted, as I think it may, to correct the record from one's impressions, noted at the time, I should say that there was an instant of undoubted totality, lasting, perhaps, one second, but not in any case; more and that the only circumstance affecting

the estimation, which might increase it, was that the light apparently shone, as I have stated, through a lunar cleft, for an instant, after the limb, properly speaking, had covered the sun.

In view of this, I think that the true totality lasted not less than $0^s.5$ nor more than 2^s, and that a mean of these times should be taken as the basis of computation.

It is evident that we were placed almost precisely on the edge of the shadow; and, in further confirmation of this, a reliable observer, Mr. Strange, who, at my request, stationed himself at the house of Luther Carpenter, described as near the railroad, two miles west and half a mile south, found the eclipse partial only, the light being too dazzlingly bright to gaze fixedly on, even at the greatest obscuration.

I have been thus prolix in describing the circumstances under which the contacts were noted as we were fortunate in being nearer the edge of the shadow than we could have designedly ventured, and, it may be hoped, successful in fixing its limit with precision. If this be the case, I shall feel in a large measure compensated for the loss of a view of the general phenomena of the eclipse, of which I saw necessarily little. I omitted to state that all the contacts were similarly recorded on the chronograph and reduced to the time by the Reardon watch.

I had a light-darkening glass before my eye, through which I noted what follows, in the very brief time presented:

On the left or eastern limb of the sun (with direct vision) were three prominent flames; the upper, about 55° from the vertex, was larger, more diffuse, softer in outline, and paler in color than the two lower—suggesting a different constitution. Of these two, the lower was about 10° above the last point where the light lingered. A group of prominences, low and prolonged, seemed to be on the right of the sun. The corona was very notably different from my anticipation, being visible through the darkening glass as a halo close to the sun, whence radiated a number of brushes of pale light, some about the solar diameter (perhaps less) in length, not noticeably curved, and suggesting at the time a comparison with the auroral streamers; though by this I do not mean to necessarily imply apparent motion. In one particular I was fortunate as a spectator.

"Baily's beads," so called, were seen for fifteen seconds or more. They were long and thin, rather than points of light, apparently moved with the moon, "went out" very much like sparks upon the edge of a piece of rough paper, and if a very deliberate view, when others were hurried, enable me to form any confident opinion, I should say were unquestionably the effect of the irregularities of the moon's contour exaggerated by irridation; at least, they presented precisely the appearance we might expect this to cause.

I am, sir, very respectfully, yours,

S. P. LANGLEY.

Professor JOSEPH WINLOCK.

The following account has been furnished by Mr. G. M. Searle, who observed the eclipse at Shelbyville:

My measurement of its duration by the stop-watch was $2^m\ 34^s.0$, but I am not inclined to give any weight whatever to this, being of the opinion that both beginning and end were observed several seconds too late, my attention being distracted by watching the movement of the shadow. This I saw immediately before the totality as a brick-red tinge on the low haze or thick air in the northwestern horizon; shortly before the end its limits were plainly visible on the sky.

About a minute or so before the totality I saw the complete disk of the moon, with the incipient corona in the form of short brushes of light perpendicular to the limb, and about 2 minutes or 3 minutes in length, apparently equably distributed. I did not notice whether these increased in length before the total obscuration, and am not sure whether I saw them with the naked eye or opera-glass. This last was a binocular marine-glass, of the largest possible diameter, furnished by Assistant G. W. Dean.

The corona, which appeared at the total obscuration, and did not, so far as I noticed, change its shape subsequently, was prolonged in four directions; at least, such is my impression, these directions being vertical and horizontal, or nearly so. Its length, in these directions, was about equal to the diameter of the moon; its shortest length about one-third of this, I should say; and it

appeared to me decidedly in the form of rays, not of concentric rings, as described, I believe, by Mr. Frankenstein.

I did not notice any protuberance immediately, but the eclipse had not lasted more than half a minute, probably, when I noticed, without specially looking for it, and I think with the naked eye, the principal protuberance apparently directly below. It appeared to me of a yellow color, and it was not till toward the close of the eclipse that it seemed to assume a deeper, or reddish tinge—I should call this color pink, properly. Half a minute, or perhaps more, before the close of the eclipse, another appeared about 10°, as I should say, below the extreme right-hand limb of the moon, but I did not notice any marked color in this, and did not look at it closely; in fact, I did not examine the other attentively, being too much engaged in looking for planets.

I did not see any stars except Venus, Mercury, and Regulus; the two first were, of course, very conspicuous during the whole of the totality. I am not sure whether I saw the latter with the naked eye or not. The darkness was not so great as to need the lantern which I had prepared for examining my chart of the heavens. Some gentlemen at my side, whom I requested to note what stars they saw, reported what evidently, from their position, must have been Arcturus, Vega, and Saturn.

Neither the beginning nor the end of the eclipse seemed to me to produce a very marked change in the amount of light, especially the former, and I did not notice the edge of the shadow moving over the landscape, though my position on the roof of the court-house was quite a high one, and commanded a fine view. My attention was, however, somewhat distracted by the sun itself.

I think that if there had been any stars as bright, or within a quarter of a magnitude as bright, as Regulus, between that star and Mercury, and within 3° of the ecliptic (at least on the northern side), I should not have failed to see them. I did not, however, see γ Leonis, or any of the other stars of that constellation. I had a spy-glass of about 1½ inches aperture, but did not use it much during the totality.

Is it not possible that the prolongations of the corona have some connection with the prominences? They seem to correspond with them in position.

The birds about the building were apparently quite excited during the totality and flew about wildly.

Mr. Alvan G. Clark, who observed the eclipse at Shelbyville through the finder of the Shelbyville equatorial, states that after the first contact, which was promptly seen by him, nothing of especial interest occurred until the sun was about half covered. Then his attention was called, by Professor Winlock, to small objects crossing the field of the finder, in straight lines, and supposed by both observers to be meteors. Mr. Clark himself observed about twenty of these objects. Mr. Clark was able to see through the finder, when opened to its full capacity (1½ inches), radial lines in the largest protuberance, which was situated near the base of the sun. On the side were two narrow, horn-like protuberances, which extended twice as far as any of the others.

Mr. J. I. Bowditch also observed the eclipse at Shelbyville. He estimated the height of the rays which proceeded from the corona at one-third of the moon's diameter. He noticed three red flames, the most brilliant of which was on the upper edge. Its height was between one-tenth and one-twentieth of the moon's diameter. Baily's beads, though looked for, were not seen, although the edge of the sun, just before totality, lost its usual smoothness. During the total phase it was easy to read fine print at half the distance required by daylight. With close attention, the second-hand of a watch could be seen. Mercury, Venus, and some of the fixed stars had a brilliant appearance.

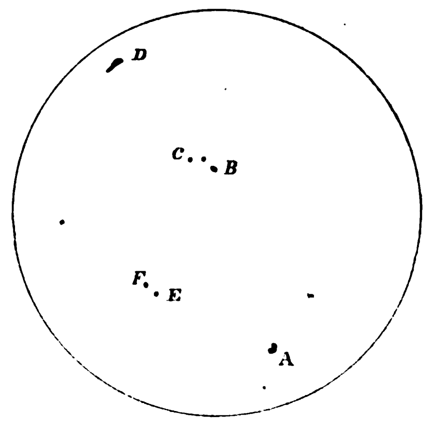
Mr. J. J. Dixwell reports to Professor Winlock that he observed the eclipse from the top of the college building in Shelbyville, Kentucky, partly with the naked eye and partly through one of Clark's navy-glasses, mounted upon a firm post. With the naked eye the corona appeared like a rim of great brilliancy, encircling the moon, gradually decreasing in brightness as the distance from the moon's edge increased, and fading wholly away at the distance of half a diameter. It exceeded in brightness full moonlight, and such an appearance might have naturally suggested to early observers on similar occasions that the moon was surrounded by an extensive atmosphere, the densest parts of which were the brightest. Through the glass the appearances were very

different. The corona spread out in rays of very irregular length, the longest of which extended more than a diameter from the moon. One observer thinks that the maximum length was one diameter and a half. Generally, the rays radiated from the moon's center, though there were some deflections. They were grouped in four great pencils or cones of irregular size, connected by shorter rays, forming together a continuous halo. The largest was on the upper left-hand limb.

Along the edge of the moon numerous tongues of intense brilliancy were distributed, one of which was particularly observed. It was on the lower limb of the moon, exceeded in size and brightness all the others, and resembled a fountain of molten metal, rising in the center to the height of about one-twentieth of the moon's diameter, overflowing on each side in the form of two arches. The light was intensely white, like that of Sirius.

Mr. Dixwell observed the contact of the moon with some of the solar spots. The time in which the record is made was found to be $55^m\ 33^s$ fast of Shelbyville mean solar time.

	h.	*m.*	*s.*
Contact with spot A	5	46	25
A entirely obscured	5	47	08
Contact with B	6	03	15
Contact with C	6	05	47
Contact with F	6	07	10
Contact with D	6	20	05
A re-appears	6	35	30
A entirely uncovered	6	35	58
D re-appears	7	13	35



REPORT BY G. W. DEAN, ASSISTANT UNITED STATES COAST SURVEY.

FALL RIVER, *September* 2, 1869.

DEAR SIR: In accordance with your instructions of June 28, I proceeded to organize an astronomical party to co-operate with a party under the direction of Professor Joseph Winlock, director of the Harvard College observatory, for the purposes of observing the solar eclipse on the 7th of August, at several of the most favorable points within the limits of the shadow in the State of Kentucky.

Shelbyville, located about thirty miles easterly from Louisville, and near the central line of the shadow, presented many favorable inducements for establishing the principal astronomical station at or near that place. Besides this, the honorable board of trustees of Shelbyville College had generously placed their large equatorial telescope at the service of Professor Winlock.

On the 12th of July, I proceeded to make arrangements for erecting the temporary observatories required for making a series of latitude-observations, and for sheltering the larger instruments to be used on the 7th of August.

Sub-Assistant F. H. Agnew, having in charge a portion of the astronomical instruments, arrived at Shelbyville on the 16th; and Mr. F. Blake, jr., aid in the Coast Survey, reported in person for duty on the 21st.

On the 22d, Professor Winlock arrived from Cambridge, and, on the following day, made arrangements for dismounting the Shelbyville equatorial, in the dome of the college-building, and remounting it near the Coast Survey station in the southwestern portion of the college-grounds. Arrangements were at the same time made for adjusting the Clark equatorial, which was to be used by Mr. J. A. Whipple, of Boston, in photographing the phases of the eclipse, under the immediate direction of Professor Winlock.

On the 24th of July, Mr. Blake began a series of latitude-observations, which he completed on the 3d of August. These consisted of one hundred and sixty-four observations, upon fourteen pairs of stars, with zenith-telescope No. 6, Coast Survey. The arc value of one division of the micrometer was determined from forty observations upon Polaris near the eastern elongation.

One set of twenty measurements with the micrometer were made in the usual manner for determining the arc value of the level-divisions.

On the 26th of July, Charles S. Peirce, esq., arrived from Cambridge, and, after examining the adjustments of his instruments, he proceeded to Bardstown, Kentucky, and there made observations with the spectroscope upon the eclipse, the results of which he has reported to Professor Winlock.

On the 3d of August, Messrs. George D. and Alvan G. Clark, the well-known opticians of Cambridge, reached Shelbyville, and soon had the large equatorial in good working order.

On the 5th of August, J. A. Whipple, esq., of Boston, joined us at Shelbyville, and, with the assistance of Messrs. George D. Clark, Albert Stevens, and J. Pendergrast, soon had the photographic apparatus in working order, and all the arrangements in detail for the photographic operations completed.

For several days immediately preceding the 7th of August the weather was particularly unpleasant, insomuch that nothing could be done, by way of adjusting the larger instruments, until the morning of the 7th, when, at 1 o'clock, the heavy clouds began to break, and in a few hours we had a clear, cool atmosphere and a cloudless sky, which continued until the eclipse observations had been successfully completed. It is perhaps unnecessary to say that this day proved an unusually laborious one to all the members of the eclipse-party, but it is gratifying to state that the faithful labors of each one were rewarded by good success.

Spectroscope.—As Professor Winlock will probably soon publish a full report of his spectroscopic observations on the solar eclipse, I will only say that he recognized *eleven bright lines*, whereas, under the most favorable circumstances, only five can generally be seen. He used the Shelbyville College equatorial, having a focal length of 9½ feet and an aperture of 7½ inches. The results from his observations will prove a most valuable contribution to science.

Photography.—Mr. J. A. Whipple, of Boston, directed the photographic operations, while Mr. George D. Clark, of Cambridge, co-operated with him, and had charge of the mechanical adjustments of the Clark equatorial, to which the photographic apparatus was attached. This instrument is 7½ feet focal length, has an aperture of 5½ inches, and is provided with an excellent clock-movement. Fifty good negatives of the eclipse were obtained, three of which were taken during the total phase. Arrangements which require no particular description here were made for recording upon the chronograph the time at which each negative was taken.

Lunar contacts and occultations of solar spots.—These were carefully observed by Mr. F. Blake, jr., aid in the Coast Survey, and myself. The instrument used by me for this purpose is an achromatic refractor, which was made at Munich, and was formerly used as a finder on the great equatorial at the Harvard College observatory. Its focal length is 46 inches, its aperture 3 inches, and on this occasion it was used with an amplifying-power of 30.

The telescope was equatorially mounted and firmly adjusted upon a pine post, about 4½ feet above the ground, and 20 feet west of the Shelbyville equatorial, which was used by Professor Winlock.

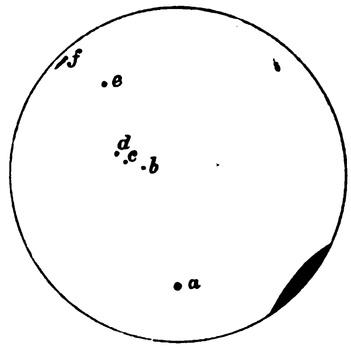
To avoid using very dark shade-glasses, the aperture was reduced to one inch by placing a paper cap over the object-glass.

Using a London smoke-shade of medium tint, I directed the telescope upon the sun, near the point of the first contact, about one minute before the first contact was recorded. I failed to detect any agitation at all of the sun's limb, and the first indication of the moon's approach was shown by the sun's limb becoming suddenly rough, yet I hesitated to break the chronograph-circuit until I could perceive a slight indentation upon the sun's limb, which, I think, must have been about five seconds after I first saw the serrated edge of the moon. A few seconds after I had recorded the first contact, Mr. Whipple obtained a good photograph of it, and the exact time was recorded upon the chronograph.

During thirty or forty seconds after the first contact, the moon's edge appeared remarkably

steady and sharply defined, its rough outline resembling very much that of a distant mountain-range. I was unable to discover that the moon projected beyond the sun. About ten minutes after the first contact the edge of the moon became tremulous, and so continued until the end of the eclipse.

The occultations of the solar spots, the approximate relative positions of which are shown in the accompanying rough sketch, were observed in the order as designated by letters.



Spot *a* being quite large, I observed two contacts of the umbra (first and last), but all the other spots were observed at the instant of occultation.

Immediately after recording the occultation of spot *e*, a very light shade-glass (London smoke) was substituted for the dark shade, and the paper cap was removed from the object-glass. After the occultation of spot *f*, the total phase of the eclipse seemed near at hand, and I watched closely for the first contact. About three seconds before this was recorded, the delicate line of sun-light suddenly separated into minute fragments, resembling very much a string of brilliants, which disappeared like snow under a white heat, producing one of the most brilliant and startling effects of the total eclipse.

I have no doubt of the fact that the dark lines which I saw for three seconds before totality were identical with the elevations that I saw upon the moon at the instant of first contact.

Immediately after I had recorded the first contact of totality, my attention was particularly directed to a large protuberance near the lower, or western edge, of the sun. For a few moments it seemed like a large coral formation, tinted with the most delicate pink and rose colors. As the eclipse progressed, several other similar formations appeared at different parts of the limb, all of which, with the corona, have been successfully photographed by Mr. Whipple.

During the totality I made a hasty survey of the heavens in the immediate vicinity of the sun, and also noticed the startling effect upon the landscape produced by the gloomy light from the corona.

The planets Mercury and Venus and the star Regulus were seen without the least difficulty, and yet the degree of darkness during totality was not so great as I had anticipated. I found but little difficulty in reading the notes that I had made in pencil. Other observers near me were differently affected, and Mr. Blake has stated in his report that he found great difficulty in reading large print.

I noticed the gradual falling of the temperature during the eclipse, and the sudden change of the wind from northeast to southeast, but at no time did I feel uncomfortably cold. According to Mr. Tevis's record, the change of temperature from the beginning until the close of the eclipse was only seven degrees Fahrenheit.

I was successful in obtaining a good observation of the second inner contact, or, in other words, the last contact of totality, but I failed to see the string of brilliants (Baily's beads), as I saw them just before the beginning of totality.

About ten minutes after the total phase I observed a faint object pass across the moon in a southwesterly direction; in a few moments I saw another, which was soon followed by another in the same general direction. Within fifteen minutes I saw ten of these faint objects pass across the moon. They had the appearance of being meteors, and I am inclined to believe that they were. The same phenomenon was observed by Mr. Blake, and also by Mr. Alvan G. Clark. The wind at that time was very light from the southeast. As my attention was required for other services, I made no observations upon the solar spots as they re-appeared.

The last contact of the moon was satisfactorily observed by Mr. Blake and myself, and, in a few hours afterward, the local time was carefully determined from a series of observations upon zenith and circumpolar stars with transit No. 4, United States Coast Survey.

Mr. Blake has made a full report of his observations upon the eclipse, which I have the honor to forward to you.

Professor C. B. Seymour, of Louisville, had the use of a small telescope belonging to the

Coast Survey (C. S. No. 24), and made such observations upon the eclipse as he was able to do. The focal length of the telescope was 28 inches; its aperture, $2\frac{1}{2}$ inches; its power, 43. The instrument was provided with a dark box, which Professor Seymour used in making his observations. I herewith forward to you Professor Seymour's report of his observations.

Sub-Assistant F. H. Agnew's impaired health prevented him from taking an active part in the eclipse observations, but he rendered valuable services in attending to the chronographs, and obtained excellent records of all the observations which were made by Mr. Blake and myself during the progress of the eclipse.

Meteorological observations were made every fifteen minutes during the progress of the eclipse by Robert C. Tevis, esq., of Shelbyville, who also rendered very acceptable services in making arrangements for the eclipse observations.

The trustees of Shelbyville College placed several rooms in the college-buildings at our disposal, for storage of the instruments and equipments, and otherwise extended every facility in their power to aid the eclipse-party.

To the Rev. Dr. Waller, Dr. Baker, Colonel W. C. Taylor, Colonel William Winlock, Joseph W. Davis, esq., and R. C. Tevis, esq., we were placed under many obligations for courteous attentions to the eclipse-party at Shelbyville.

As your instructions contemplated the occupation of one or more stations near the northern and southern limits of the shadow, Falmouth at the north, near the Cincinnati and Lexington Railroad, and Oakland at the south, near the Louisville and Nashville Railroad, were considered most favorably located for this purpose, and arrangements were accordingly made for having those stations connected by telegraph for an hour during the eclipse.

John Van Horn, esq., general superintendent of the Western Union lines, and Mr. William Biggart, superintendent of the railroad-lines, generously placed their wires at the disposal of the Coast Survey, and cheerfully extended all the telegraph facilities without charge.

The eclipse-party at Falmouth was placed in charge of Mr. Arthur Searle, of the Harvard College observatory, who, on the 5th of August, proceeded to complete the requisite arrangements at that place.

Mr. Searle was fortunate in securing the services of several gentlemen at Falmouth, who kindly volunteered to aid him in making observations during the eclipse. The party was provided with two good telescopes, a clock-pendulum adjusted to sidereal time, two Morse registers, a stop-watch, and several other smaller instruments. The chief object of the observations near the north and south limits of the shadow was to determine the duration of the total phase, and, although Mr. Searle's efforts to obtain a good record of his observations upon the Morse registers were not successful, he thinks that the observations made by Captain W. E. Arnold, of Falmouth, who was assisted by two tallymen, Messrs. B. Johnson and D. Yelton, are worthy of confidence. The times noted by Captain Arnold gave forty-five seconds for the duration of totality, but he thinks that it was a small fraction of a second less. Captain Arnold's observations were confirmed by Mr. Woodson, who was assisted by a friend, using an ordinary watch. Mr. Woodson thinks that the total phase continued exactly forty-five seconds.

The station is located near the railroad and west of Watson's hotel, and was marked by a stake driven into the ground.

Mr. R. W. Grant made observations on the first hill north of Falmouth station, using a stop-watch, and found the duration of the total phase to be forty-one and six-tenths seconds. Judge Hudnall observed at the same station, using an ordinary watch, and made the time of totality a small fraction of a second greater than forty-one seconds.

At Catawba, a few miles north of Falmouth, the total phase was observed by Mr. D. Crozer, jr., and ascertained to be twelve seconds. Mr. Crozer's observations were timed with an ordinary watch by his father; and Mr. Searle reports that Mr. Crozer will at once mark the point by a stake.

The eclipse-party at Oakland, Kentucky, was in charge of Professor S. P. Langley, director of Alleghany Observatory, who was assisted by Graham Wilder, esq., and Mr. N. De Brie, of Louisville.

The station at which the observations at Oakland were made is located about half a mile west

of the railroad-station at that place, and twenty yards from the track. The point is to be marked by a large stone sunk into the ground. Professor Langley's party were provided with a good telescope, and a Bond chronograph-register from the Alleghany Observatory, a zenith-telescope for determining the latitude, a clock-pendulum, pocket-chronometer, stop-watch, and other smaller astronomical instruments.

The unfavorable weather before the 7th of August prevented the latitude observations, but it was supposed, from the information obtained from the best maps, that the station was at least two miles within the shadow. The observations of the totality appear to show that the observers were located just within the shadow.

Professor Langley's observations were made with a telescope having an aperture of three inches, and magnifying-power of thirty, and were recorded upon a Bond chronograph. These observations show that the duration of totality was one and seven-tenths seconds, but Professor Langley thinks it was not much longer than one second.

Mr. Wilder used a binocular field-glass, and his observations were recorded upon a Morse register fillet, and indicate a duration of two seconds. He, however, remarks, in his record, that, in his judgment, the duration of totality could not have been more than three-fourths of a second or one second.

Mr. De Brie's record was not entirely completed, but in his record-book he remarks that, after recording the first contact on the Morse fillet, he counted one beat of the pendulum, when the sun re-appeared, and he thinks that the duration of the totality did not exceed one second of time. Mr. De Brie used no glass in observing the contacts.

Professor Langley remarks in his record that two observers, who were stationed at Mr. Luther Carpenter's house, which is located near the railroad, about two miles west, and a little south of Oakland, were quite outside of the shadow of the eclipse.

The Coast Survey is under obligations to all the gentlemen who took part in the eclipse observations at Falmouth and Oakland, and my thanks, in behalf of the Coast Survey, are due to John Van Horn, esq., general superintendent of the Western Union Telegraph, and to Messrs. Carter and Boyle, telegraph-managers at Louisville.

Mr. Albert Stevens, of Cambridge, performed the duties of artificer at Shelbyville in the most faithful and acceptable manner.

Very respectfully,

GEO. W. DEAN,
Assistant.

Professor BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

REPORT BY F. BLAKE, JR., UNITED STATES COAST SURVEY.

BOSTON, MASSACHUSETTS, *Tuesday, August* 24, 1869.

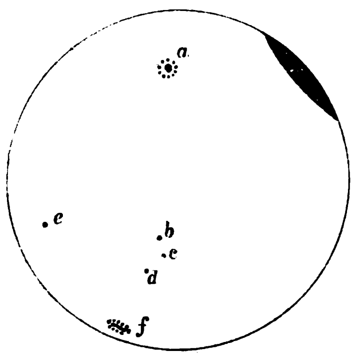
SIR: I herewith transmit a report of my observations of the total solar eclipse, made on the 7th instant, at the Coast Survey station, Shelbyville, Kentucky.

The morning of Saturday, August 7, 1869, opened with a cloudless sky, and throughout the day the atmosphere was of a remarkable clearness. At 8 o'clock a. m., the mercury indicated a temperature of 59° Fahrenheit, it being the lowest reading I had made for at least two weeks. The morning was passed in making the necessary preparations for the afternoon's observations. The instrument used by me was the "Bowditch comet-seeker," belonging to the Harvard College observatory, the object-glass of which is 4 inches in diameter, and its focal length 3 feet; the power used was 34. This instrument was mounted upon a cedar post, about 70 feet south of the observatory, in which were placed the two chronographs and the break-circuit chronometer. The break-

circuit key at my instrument and the photographic apparatus attached to the Clark equatorial were in one circuit; therefore, my observations of contacts and occultations were recorded by the Harvard chronograph upon the same sheet which contains the record of the times at which the several photographs were taken. To facilitate the sketching of the apparent positions of the solar spots, I stretched four spider-lines across the diaphragm of the comet-seeker, dividing the field approximately into octants. A brass slide, in which were set a number of colored glasses of different shades, was attached to the eye-piece; and a pasteboard cap, which reduced the aperture to about an inch and a quarter, was placed over the object-glass.

A chart, showing the positions of the planets and constellations at the time of totality, a small sextant, a few sheets of writing-paper, and a common watch, with which to note approximate times, were the only additional apparatus. The eye-piece of the comet-seeker is at the extremity of the horizontal axis, and, when observing, I sat with my face to the north.

The first exterior contact, as observed by me, is worthless. I was devoting my attention to a portion of the sun's limb much below the point at which the contact took place, and did not break the circuit until some ten or twelve seconds after the time at which Alvan G. Clark, jr., exclaimed, "There it is!" He was looking through the finder of the Shelby equatorial, and was probably the only member of the party who observed this contact. The moon had the appearance of a jet-black body projected upon the bright surface of the sun, its edge being slightly irregular. I am quite confident that the moon's limb was not visible until the contact actually occurred. The moon's disk did not apparently project beyond that of the sun. The accompanying sketch shows the approximate positions of the solar spots as they appeared through my instrument just after the first exterior contact.



The first spot (a) was quite large, and in observing it I made three breaks: one as the moon came in contact with the first edge; a second as it reached the center of the spot; and a third as the last edge disappeared. I have but little confidence in the observation on the center. After this occultation had been successfully observed, I could but notice the calmness of the observers and the smoothness and precision with which the different observations were made.

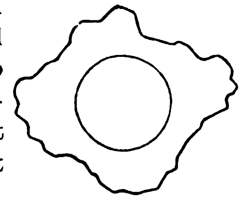
About twenty-eight minutes before totality, the wind, which had been from the northeast, suddenly ceased. In a few minutes, however, a breeze sprang up in the southeast and continued to blow from that quarter during the remainder of the day. At the same time I noticed that shadows were quite indistinct; that the air was growing chilly; and that the sun-light gave a peculiarly gloomy aspect to the landscape.

The remaining spots (b, c, d, and e) were small, and but one tap was made on each of them. They remained steady and undistorted up to the time at which they were occulted.

Thirteen minutes before totality the air felt quite cold; the sun appeared as a beautiful crescent, while the black edge of the moon seemed to stand out from it, giving one the idea of a stereoscopic picture. The shaking, or "running," of the moon's edge seemed to be rapidly increasing. Giving a hurried glance about me, I was struck with the appearance of the trees to the eastward of the tent and about 50 feet distant; the foliage was of a peculiar color, very similar to that produced by the electric light when displayed at night by Mr. Ritchie, of Boston, Massachusetts.

Eight minutes before totality, the limbs of the sun and moon were shaking violently, and the sun-light was diminished to such an extent that the faces of the observers were of a livid hue, not unlike that of a corpse. Facing to the eastward, I saw that the southern edge of my shadow was comparatively sharp and distinct, while the northern edge was ill-defined and very faint. The sun was now reduced to an extremely thin crescent, and I began to watch for the first interior contact. A few moments before totality I noticed a slight agitation in the upper portion of the crescent, which immediately afterward broke up into little detached masses of light, of very irregular shapes and sizes, and at unequal distances from each other. This phenomenon, commonly known as "Baily's beads," lasted but a few moments. These little points of light were rapidly extinguished; and as the last one, with the only remaining ray of sun-light, was cut off, I made a break with the key, the chronographic record of which gives the time of the first interior contact.

With the extinction of that last ray a startling change took place. The corona, of which, up to this moment, there had been positively no indications, now appeared as an extremely soft white light, surrounding the sun and extending from it, in all directions, to a distance of at least two-thirds of its diameter. There was no appearance of rays, nor was there any sparkling light; it had, in fact, a perfectly dead or "set" look. Its general form was irregular and somewhat similar to that of this rough sketch, which is copied from the one I made at the time.



Simultaneously with the appearance of the corona, some of the planets and larger fixed stars became visible to the naked eye. They did not appear as they ordinarily do at night, but seemed to shine with a very soft and slightly diffused white light. The sky, in the vicinity of the sun, was not blue, as at night, but was of a peculiar milky hue; in the zenith it seemed to be of a purplish tinge, and had a more gloomy aspect; the eastern sky was lighted up with a lurid glare similar to that which sometimes attends an autumn sunset. I noticed several pink-colored protuberances on the apparent right-hand limb of the sun and one very large one on the lower limb. Like the corona, they seemed to be devoid of life. The darkness was so great that it was impossible to distinguish the foliage of trees a few rods distant, they being visible as dark bodies, the outlines of which were projected on the sky. At a distance of about one foot and a half I was unable to read the names of the planets upon the chart; on referring to it, I find they are of this size:

Venus. Mars. Mercury.

During the totality I felt quite uncomfortably cold, and was at first very much surprised on finding that the mercury had fallen but five degrees. I recollected, however, that, as I had been fully exposed to the sun, in a place where the radiation was very great, it was quite probable that I had experienced a change of temperature which would have caused the thermometer to fall thirty or forty degrees.

After having devoted about two minutes to observations of the general phenomena, I again sat down at the instrument and began to watch for the re-appearance of the sun. The edge of the moon surrounding the point at which the emersion was to take place gradually became brighter and brighter, until a single ray of sun-light burst forth, and, a break having been made with the key, the observation of the last interior contact was accomplished.

Soon after the re-appearance of the sun my attention was attracted to bright points of light, which were, from time to time, passing across the field. After observing fifteen or twenty of them, I concluded that they passed between the earth and the dark body of the moon; that they always fell in the same direction, which was from the apparent upper limb of the moon to the horizon; that their paths were straight lines, and parallel to each other; that one seen by Mr. A. G. Clark, jr., through a telescope, which was seven feet south and twenty feet east of my instrument, was also seen by myself; and that they were incandescent bodies. In size they were equal to the smallest stars visible through any telescope; about as large as a tenth or an eleventh magnitude star appears to be in the Harvard College equatorial. As the sun-light increased these meteors ceased to be visible. As I was not looking through the telescope during the total phase, I am unable to say whether or not they were then visible.

The time between the disappearance of the meteors and the last exterior contact being occupied in writing out notes, no observations of the emersions of the solar spots were attempted.

My work terminated with a very successful observation of the last exterior contact, which was not accompanied by any very striking phenomena. The limbs of the sun and moon showed no signs of distortion up to the instant at which they separated.

In the following table, which contains the results of my observations of precision, the chronometer-times are those which have been read directly from the chronograph-sheet; the true sidereal times have been deduced from the chronometer-times by applying to the latter the Δt computed from time observations made with Coast Survey transit No. 6 during the morning preceding and the evening following the eclipse.

Phenomena.	Chronometer time.			True sidereal time.			True mean time.		
	h.	*m.*	*s.*	*h.*	*m.*	*s.*	*h.*	*m.*	*s.*
First exterior contact	14	25	47.00	13	33	55.86	4	28	5.39
Spot *a*, First edge		48	50.20		56	59.09			
Spot *a*, Center		49	5.60		57	14.49			
Spot *a*, Last edge	14	49	15.19	13	57	24.08			
Spot *b*	15	5	30.68	14	13	39.60			
Spot *c*		6	59.46		15	8.38			
Spot *d*		8	22.20		16	31.12			
Spot *e*		9	39.69		17	48.61			
First interior contact		24	28.81		32	37.75	5	26	37.67
Last interior contact	15	27	2.80	14	35	11.75	5	29	11.24
Last exterior contact	16	21	2.98	15	29	12.01	6	23	2.66

Duration of totality, $2^m\ 34^s.00$.

F. BLAKE, JR.,
United States Coast Survey.

Assistant GEORGE W. DEAN,
United States Coast Survey.

Professor C. B. Seymour reports as follows:

Immediately before the eclipse seven spots were visible. My watch was not very accurate, so that the times are only approximate.

Spot 2 was large and circular, about 135° from the north point, and distant half a semidiameter from the center.

Spot 1, almost due north of spot 2, and about 120° from the north point, was quite moderate in size.

Spot 3, about 288° from the north point, not far from the center, was small.

Spot 4 was at about the same angular distance, and twice as far from the center.

Spots 5 and 6 were near together, and about three times as far from the center as spot 3, and very small, about 280° from the north point, thus $\dot{3}\ \ \dot{4}\ \ \dot{5}\ \ \dot{6}$

Spot 7, about 280° from the north point, was a longish oval, at about one-sixth of the semidiameter from the edge of the sun.

At $4^h\ 27^m\ 45^s$ the contact was on a little distance. I failed to see the instant of contact.

At $4^h\ 49^m\ 00^s$ spot 1 disappeared.

At $4^h\ 51^m\ 03^s$ center of spot 2 was covered.

At $5^h\ 07^m\ 30^s$ spot 3 disappeared.

At $5^h\ 08^m\ 00^s$ spot 4 disappeared.

At $5^h\ 09^m\ 50^s$ spot 5 disappeared.

At $5^h\ 10^m\ 11^s$ spot 6 disappeared.

At $5^h\ 24^m\ 30^s$ center of spot 7 disappeared.

At $5^h\ 26^m\ 20^s$ beginning of total phase; beads appeared on the edge of the shadow.

At $5^h\ 28^m\ 50^s$ total phase had just ended; I failed to see the instant of end; beads were breaking up when first seen.

During the total phase a kind of luminous, irregular twinkling was observed in the dark box on the paper, extending about 45° each side of the north point. I saw no protuberances on the paper. On raising my eyes to the sun, I saw a red protuberance near the north point and a larger one almost vertically below the sun's center. I saw Mercury and Venus with the naked eye. An irregular corona surrounded the sun at totality.

At $5^h\ 41^m\ 55^s$ center of spot 2 re-appeared.

At $5^h\ 42^m\ 00^s$ spot 1 re-appeared.

At $6^h\ 04^m\ 00^s$ I observed a spot, from which the moon's shadow had just passed, about 225° rom the north point. This I style spot 8. I had not observed it before.

At 6^h 05^m 00^s moon's shadow had just passed spot 3.
At 6^h 05^m 40^s spot 4 re-appeared.
At 6^h 06^m 45^s spot 5 re-appeared.
At 6^h 07^m 15^s moon's shadow had just passed spot 6.
At 6^h 18^m 15^s center of spot 7 appeared.
At 6^h 22^m 43^s last contact observed.

As nearly as I could approximate, the moon's body obscured the sun's center at 4^h 59^m 00^s, and left it at 5^h 56^m; but these observations of the center are only rudely approximate.

These observations were made upon the image of the sun's disk, cast through a telescope upon a sheet of paper, on which was a circle divided into octants. The lines in the telescope cast a shadow falling exactly on the lines on the paper dividing the octant.

OBSERVATIONS AT SPRINGFIELD, ILLINOIS.

COAST SURVEY OFFICE,
Washington, D. C., October 4, 1869.

DEAR SIR: The party for observing the solar eclipse of August 7, at Springfield, Illinois, acting under your immediate direction, and organized by me in accordance with your instructions of June 25, consisted of the following members: L. F. Pourtales, assistant, United States Coast Survey; Professor J. M. Peirce and J. B. Warner, of Harvard College, stationed at Bloomington, Illinois, on the 7th; E. P. Seaver, R. A. McLeod, C. N. Fay, and W. P. Montague, of Harvard College, temporary aids; J. W. Black, assisted by R. Fitzgerald, photographers; and myself.

The special duty assigned to the party was to obtain measures of precision of the contacts, and to make such collateral observations of the corona, prominences, &c., as the outfit of the party permitted.

Preparatory to these observations, Mr. E. P. Austin determined, under Assistant E. Goodfellow's direction, the latitude and longitude of a station in the grounds of the new State-house. Between May 19 and June 6, on eight nights, sixty-five observations were taken on eighteen pairs of stars, with zenith-telescope Coast Survey No. 5, for the determination of the latitude. The results are as follows:

Pairs of stars, B. A. C.	Seconds of latitude.	Pairs of stars, B. A. C.	Seconds of latitude.
	"		"
3959 and 3990	56.24	4564 and 4594	57.14
4033 and 4066	56.74	4607 and 4640	56.40
4110 and 4159	56.52	4675 and 4684	56.65
4196 and 4217	56.35	4701 and 4723	56.21
4258 and 4311	57.39	4738 and 4758	56.15
4341 and 4360	56.68	4789 and 4809	57.04
4387 and 4416	57.10	4870 and 4897	56.40
4438 and 4479	57.07	4958 and 5026	56.80
4519 and 4552	57.28	5071 and 5143	57.48

Mean result for latitude.......................... $39°\ 47'\ 56''.75 \pm 0''.07$
Probable error of a single observation for latitude.. $\pm 0''.51$
Probable error of a star's place .... $\pm 0''.10$

It was deemed unnecessary to give special weights for number of observations.

For the determination of the longitude, transit-observations (with a portable Würdemann transit, No. 6 of the United States Naval Observatory) were made May 19, 22, and 31, and June 2 3, 4, and 6; and chronometer-signals were exchanged by telegraph between Omaha, Nebraska; and Springfield, Illinois, on three nights, with the following results:

Difference of longitude, Springfield and Omaha.

	May 22.	June 2.	June 4.	Mean.
	m. s.	*m. s.*	*m. s.*	*m. s.*
Springfield signals..............series 1..	25 08. 31	25 08. 41	25 08. 24	25 08. 32
2..	08. 22	08. 47	08. 27	08. 32
3..	08. 34	08. 45	08. 33	08. 37
Mean..............................	25 08. 29	25 08. 44	25 08. 28	25 08. 34
Omaha signals...................series 1..	25 08. 85	25 08. 86	25 08. 72	25 08. 81
2..	08. 70	08. 79	08. 74	08. 74
3..	08. 78	08. 84	08. 74	08. 79
Mean..............................	25 08. 78	25 08. 83	25 08. 73	25 08. 78
Mean from Springfield and Omaha signals	25 08. 54	25 08. 63	25 08. 51	25 08. 56
Approximate correction for personal equation between Mr. Goodfellow and Mr. Austin.				+0. 13

We have the Coast Survey telegraphic results—

Cambridge, east transit, west of Greenwich.........	$4^h\ 44^m\ 30^s.93 \pm 0^s.23$
Reduction, east to west, transit at Cambridge.......	$+\ 0^s.06$
Omaha, west of Cambridge (west transit)..........	$1^h\ 39^m\ 15^s.04 \pm 0^s.06$
Springfield, east of Omaha.........................	$25^m\ 08^s.69 \pm 0^s.11$
Hence Springfield west of Greenwich...............	$5^h\ 58^m\ 37^s.34 \pm 0^s.26$
	$89°\ 39'\ 20''.10 \pm 3''.90$

The station is marked with a stone 15 inches square, set in the ground 7 feet, and above ground with a block of stone 2 feet high; it is on the west side of the foundation of the new State-capitol, and is fully described in the records. A meridian line was also traced out by Mr. Austin, with the northern termination marked by a stone.

On July 20, Assistant Goodfellow arrived at Springfield, and on July 21, Assistant Pourtales; the latter selected a station in the grounds of the reservoir, about one and one-fourth miles north-east of the center of the city, favorably situated for observing the eclipse. Under Assistant Goodfellow's direction, an astronomical observatory was erected 10 feet by 12 feet, and 7 feet high at the eaves; Troughton and Simms's transit, Coast Survey No. 6, was mounted on two blocks of seasoned pine; the Krille clock was mounted on a post; and chronograph Coast Survey No. 2 (by Bond) was set up. A Daniell battery of three cups was kindly loaned by the Western Union Telegraph office. On my arrival at Springfield, on the 28th, the observatory was enlarged to meet the wants of the photographers; a dark chamber, 4 feet by 10 feet, was added on the west side; also sufficient covered space for mounting and working the large equatorial. A full description of the station is given in the records. To connect the two astronomical stations, a small triangulation was executed (see accompanying sketch, Plate No. 25, Fig. 7), and a base-line measured 520.6 feet long; also an astronomical azimuth determined by means of the sun. The line was measured twice with a patent metallic tape. We have, by triangulation—

Eclipse-station north of Austin's station	$1'\ 05''.75$
Eclipse-station east of Austin's station	$0'\ 55''.87$

Hence, for the position of the eclipse-station (center of transit),

$$\varphi = 39°\,49'\,02''.50;\ \lambda = 89°\,38'\,24''.23, \text{ or } 5^h\,58^m\,33^s.62 \text{ west of Greenwich.}$$

The triangulation also gave the following results:

	Latitude.	Longitude.
	° ′ ″	° ′ ″
New State-house, center of dome....................................	39 47 56.71	89 39 17.73
Old State-house, pole on cupola	39 48 06.51	89 38 54.76
Leland Hotel, pole on cupola..	39 47 57.47	89 38 53.35
Elevator, pole on roof	39 48 09.62	89 39 07.18
Reservoir, column	39 49 04.30	89 38 19.71

I observed transits for local time on July 28, 29, 30, and 31, and again on August 2, 3, 4, and 7. Those for the last three dates were carefully reduced by the method of least squares; the chronograph-sheets being read off to the nearest $0^s.02$. The clock corrections are as follows:

1869.	Sidereal time.		
August 3....	17^h	Clock correction on Springfield, sidereal time....	$+2^s.16 \pm 0^s.02$
August 4....	$17\frac{1}{2}^h$	Clock correction on Springfield, sidereal time....	$+3^s.02 \pm 0^s.02$
August 7....	18^h	Clock correction on Springfield, sidereal time....	$+2^s.80 \pm 0^s.01$

Two mean-time chronometers were rated by tapping their beats; their corrections on Springfield mean time are as follows:

Dent 2171.	h. m. s.
August 2, at $8\frac{3}{4}$ p. m	−0 50 34.9
August 3, at $8\frac{3}{4}$ p. m	34.2
August 4, at 9 p. m	33.1
August 5, at 5 p. m	32.3
August 6, at 4 p. m	29.5
August 7, at noon	22.32
August 7, at $9\frac{1}{2}$ p. m	22.40
August 9, at $2\frac{1}{2}$ p. m	−0 50 20.9

N. B.—Between the 6th and 7th the chromometer was taken to the telegraph-office and probably suffered some change on the return on the 7th a. m.

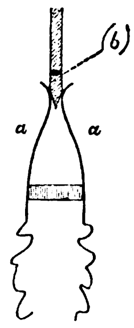
Parkinson and Frodsham No. 1411, used at Bloomington on the 7th, has the following corrections to Springfield mean time:

h. m.	*h. m. s.*
August 2, at 8 45 p. m	+ 4 32 47.0
August 3, at 8 45 p. m	46.2
August 4, at 9 00 p. m	38.9
August 5, at 5 00 p. m	34.6
August 6, at 4 00 p. m	33.5

On the nights of the 6th and 7th time-signals were sent to Des Moines, Iowa.

Transits of solar spots, according to Carrington's method, were observed on several days, but, owing to the want of fine motion and means of adjustment of equatorial No. 4, and a troublesome wind, these observations are not so accurate as the method admits of when under favorable circumstances.

The photographic pictures of the eclipse were obtained by means of an equatorially mounted (on a Smeaton block) refractor by Dollond, having about $6\frac{1}{2}$ feet focal length and a clear aperture of 4 inches. The instrument was adjusted so that by merely turning the handle of the motion in right ascension the image of the sun could be kept near enough in the middle of the field during the total duration of the eclipse. The use of photography at the Springfield station was decided on but a short time before the eclipse, and was much restricted for want of clock-motion in the telescope, and also for want of a suitable eye-piece. The images of the sun, as formed by the object-lens, are nearly two-thirds of an inch in diameter. The pictures were taken instantaneously, and the times recorded automatically on the chronograph. The attachment of the plate-holder and the slide and circuit-breaking arrangement is due to Mr. Black. The drop-slide had a rectangular adjustable opening of about one-twelfth of an inch, and passed over the diaphragm of the telescope in a small fraction ($\frac{1}{30}$) of a second. The telescope was directed by means of the finder, which, in the place of the eye-piece, was closed with a ground glass, having a circle marked on it. When the image of the sun was kept within this circle, the telescope war properly directed and the solar image was central on the plate. Each plate was arranged for five pictures, which, on the average, were taken within an interval of about nine seconds. When the middle of the opening was opposite the center of the solar image, the lower end of the slide separated two slender brass springs (*a*, *a*) in connection with the galvanic circuit, and broke the circuit; about one-tenth of a second later



the circuit was restored by a metallic plate inserted in the wooden slide (near *b*) coming in contact with the springs. For each picture exposed there are two marks on the chronograph—one produced by the *up*-motion of the slide, while the plate is covered; and one produced by the *down*-motion; the former being larger and useful as a finder for the latter. During totality the slit was opened to the full size of the picture, but, as the photographs show, the sun was but very imperfectly followed by hand, making a series of superimposed pictures, from which, nevertheless, some useful information may be gathered. After totality, the circuit became, from some cause, disarranged, and interrupted for a few minutes the regularity of the operation. Assistant Pourtales timed the pictures; Mr. Black attended to the slide and exposure; Mr. Fitzgerald kept the telescope directed; while two attendants in the dark room, directly back of the telescope, did the coating and developing, and fixing of the plates. In all, 52 plates were secured, throwing out those taken before and after the eclipse, and some on which an attempt was made to let the sun trace out a declination-parallel to serve for the measure of position-angles. After this deduction, 38 remain, containing 178 pictures of phases and 6 pictures during totality.

As some time must necessarily elapse before the measures of the photographic pictures (glass negatives) can be taken and discussed, I propose to submit a special (and supplementary) report of these results, in order not to delay the present general account of our labors.

The weather was remarkably favorable; the cloudy and rainy weather of the two preceding days having changed during the night, and on the day of the eclipse the sun was clear and no cloud was to be seen. There was a light wind from the northeast. It was also fortunate that the dust of the preceding dry period had all disappeared. Meteorological observations were taken by Mr. T. Dudley, a Smithsonian observer, who had kindly volunteered his services. His record is given further on.

My observations of the contacts and of the general progress of the eclipse were made with the zenith-telescope already mentioned. It has a clear aperture of 3.65 inches, and a focal length of 4 feet 2 inches. The magnifying power used was about 65, the lowest available. A deep-red shade-glass was fastened over the inverting eye-piece. The high power and the presence of micrometer rack and threads made the use of the instrument less convenient. Mr. Seaver used the small equatorial, also employed by me in the solar-spot observations. Its aperture was 2.7 inches; focal distance, 3 feet 10 inches; and magnifying power, about 55. No shade-glass was required, as the sun's image was spread on the disk to a circle of 4¾ inches in diameter. The instrument was balanced and roughly adjusted, but for want of fine motion was troublesome to handle. Mr. Fay observed with telescopes of one and two inch opening, and Mr. McLeod with a binocular marine-glass, magnifying two or three times. These observers used red shade-glasses.

The contacts were noted as follows, Mr. Montague calling out the half and whole seconds of the chronometer (Dent 2171):

	h.	*m.*	*s.*
First outer contact at	4	55	19.5, by Charles A. Schott.*
			21.0, by R. A. McLeod.
			22.0, by E. P. Seaver.†
			17.3, by C. N. Fay.‡

The mean of these times, giving the second and third half weight, is $4^h\ 55^m\ 19^s.4$.

	h.	*m.*	*s.*
First inner contact at	5	55	54.5, by C. A. S., well observed, counting beats myself.
			55.5, by R. A. McL.
			56.5, by E. P. S.
			55.0, by C. N. F., allowing 3^s for lateness.

* The contact happening nearly one-fourth of a minute later than the time predicted from the Nautical Almanac data, and the field of view being comparatively narrow, I swept a little to the right and left of the point of contact, and estimated the correction to my time ($4^h\ 55^m\ 23^s.5$), when the phase was distinctly seen, about $4^s.0$, judging by the same size of phase at the ending of the eclipse.

† Time uncertain; 6^s deducted from observed time, when the sun showed a decided indentation; see special report.

‡ One second deducted from recorded time; see special report.

Giving half weight to the second value, and none to the remainder, we have $5^h\ 55^m\ 54^s.8$.

	h. m. s.	
Second inner contact at	5 58 43.5,	by C. A. S., well observed.
	43.5,	by R. A. McL.
	43.5,	by E. P. S.
	42.5,	by C. N. F.

Omitting the last, we have $5^h\ 58^m\ 43^s.5$ for end of totality.

	h. m. s.	
Second outer contact at	6 54 07.8,	by C. A. S., well observed, counting time myself.
	07.5,	by R. A. McL.
	07.5,	by E. P. S.
	08.5,	by C. N. F.

For the end of the eclipse, I prefer to use the first value alone, or $6^h\ 54^m\ 07^s.8$.

Applying the chronometer-correction ($-0^h\ 50^m\ 22^s.4$), we have the following observed times of the contacts; to these are added, for comparison, the deduced times from data and formulæ given in the Supplement to American Ephemeris, 1869:

Springfield, mean time.

	Observed. h. m. s.	Predicted.* h. m. s.	Diff. O.—P. s.
Eclipse begins....	4 04 57.0	4 04 35.5	+ 21.5
Totality begins...	5 05 32.4	5 05 20.7	+ 11.7
Totality ends.....	5 08 21.1	5 08 10.2	+ 10.9
Eclipse ends	6 03 45.4	6 03 41.2	+ 4.2

	h. m. s.	
Total duration of eclipse, by observation,	1 58 48.4	Diff. $17^s.3$
computation,	1 59 05.7	
Duration of totality, by observation,	2 48.7	Diff. $00^s.8$
computation,	2 49.5	

The observed time of beginning must be considered liable to a proba ble error of several seconds, and is most likely too late; the times of the other places are considered quite trustworthy. An independent set of times, of greater value it is expected, will be deduced from the photographs.

It may also be stated here that the nearest point in the line of centrality of shadow, as computed from the American Ephemeris, was 0′.7 N. 32° E. from the eclipse-station; according to the data from the English Nautical Almanac, however, this distance was 3′.0, in the same direction. The elevation of the station above the sea-level I estimate at about 500 feet.

The contact of the moon's limb with the umbra of spot 4 (see solar spot-diagram further on) was observed as follows:

	h. m. s.	
First contact occurred, by chronometer 2171 . at	5 19 45.5, C. A. S.	For center of umbra:
	43.5, E. P. S.	Mean, $5^h\ 20^m\ 02^s.5 = 4^h$
Umbra disappeared at	5 20 19.5, C. A. S.	$29^m\ 40^s.1$ Springfield
	21.5, E. P. S.	mean time.

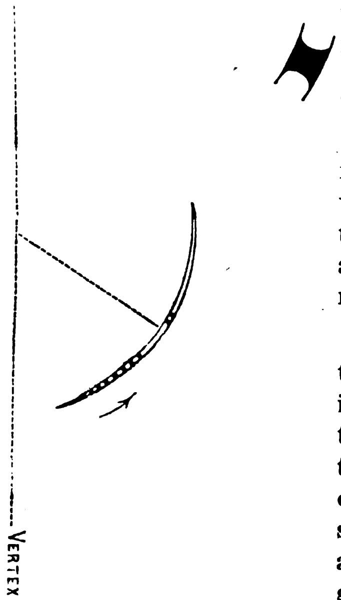
In connection with this observation I noticed a curious and unexpected phenomenon. When the moon's limb had nearly touched the penumbra of the spot, a black band † suddenly shot out from the umbra (and of the same width), and for an instant was connected with the moon's limb; it then retreated and re-formed, making apparently a bridge across the penumbra; it was then gradually shortened and covered by the advancing moon. This connection was distinctly seen for several seconds, though each forming, retreating, and re-forming was, perhaps, completed in half a second.

* $5^h\ 08^m\ 11^s.75$ is the longitude of the Washington Observatory here assumed.

† Otherwise known as the black ligament, I believe, and giving rise to a real and an apparent contact.

		h. m. s.
I noted contact (by chronometer) with spot	7	at 5 36 25.5.
	7½	at 5 37 51.0.
	8	at 5 39 20.5.
	9	at 5 53 50.5.

The above disappearances were also noted by Mr. Seaver, together with re-appearances; for which see his report. During the progress of the eclipse, the moon's outline was tolerably smooth, and the points of the crescent were perfectly sharp.* The phenomenon of Baily's beads was seen to great perfection for a few seconds before totality set in, but its existence just after totality was not ascertained, the time being consumed with fixing my shade-glass. The accompanying diagram shows the beads, as seen through the inverting telescope. The arrow indicates the direction of their successive formation; the two upper ones were formed last. I would particularly notice their great regularity in width, outline, and distribution. Their individual shape is given in the corner of the diagram. The phenomenon was seen, both before and after totality, by others of the party, and is described in their reports.



Baily's beads before totality.

In the accompanying sketch (Plate No. 25, Fig. 8), I have tried to produce a faithful picture of the corona and prominences during totality. It is drawn, relatively, to scale and the coloring is that seen by me. The corona appeared white, with the slightest mixture of a very faint amber-colored warmer tint, and the prominences of a bright red. The relative darkness of the sky and moon is preserved. The various directions given on the margin are the result of a computation. The position of the prominences are from our photographs, and the outline of the corona from the experienced pencil of Mr. F. B. Meek, of the geological survey of Illinois, who kindly consented to attend to this phenomenon. (Plate No. 25, Fig. 9.) In general, the outline of the corona was quite well defined, and to some presented five, to others, perhaps the majority, four cusps or brushes of light. It was striated and extended all round the covered sun; to the naked eye the maximum extent of the bundles of rays was nearly three-fourths of the sun's radius, but, in general, the coronal development was no greater than about one-fifth of the radius.

The accompanying sketch (Plate No. 25, Fig. 10) is intended to exhibit the symmetrical relation of the corona to the sun's equator. There are two (principal) bundles of rays to the west in about 52° heliographical north and south latitude, and two (principal) bundles of rays to the east in about 32° north and south latitude, with a feebler development of rays between the latter and over the equatorial region. The rays do not converge to the sun's apparent center.

The large prominence, near the lowest point of the sun, was seen first with the naked eye, and was the only one remaining visible throughout the totality. Those on the eastern limb appeared immediately after totality set in; two of those were separate from the rest, which consisted of two large patches of intensely bright light of a white color, whereas all other prominences were of a delicate pink. When the three prominences on the western limb had become fully uncovered by the retreating moon, all traces of those on the eastern limb were gone. A few seconds before the end of totality, a long, narrow ridge of red-colored matter, united the largest and lowermost prominence with the next one to the westward. On the following limb the chromosphere was whiter than on the preceding limb; its thickness on the latter I estimate at less than half a minute, and widest in the middle of its extent. The elevation of the lower prominence was about 1′.8; somewhat less than three turns of the micrometer.

* The phenomena of distortion, noted by Mr. McLeod, I therefore attribute to the imperfection of his marine-glass.

We have the following approximate position-angles (from the photographs), counted from the north, through the east:

Of the range of flame-like matter on following limb between..	76° and 135°
First isolated prominence, same limb........................	150°
Second isolated prominence, same limb.....................	161°
Largest cloud-like prominence on lower limb.................	232°
Small prominence on preceding limb.........................	282°
Winged prominence on preceding limb......................	288°
Flame-like prominence on preceding limb...................	314°.5

A small triangular prominence was also seen on the western limb; position probably in 344°, but doubtful.

Relative to the solar equator, the chromosphere and prominences do not appear in any high north or south latitude; thus, in common with the corona, these phenomena seem to have some relation to the sun's axis.

When viewed with a high power they appeared with the most distinct outline, and were objects of exquisite beauty. The careful drawings made of their form will admit of a some-

Prominences on the western limb of the sun, near the close of tatality.

what closer description and scrutiny; of those examined by me, after the midddle of totality and within half a minute of its close, they were all on the preceding limb. The largest prominence, opposite the vertex, No. 1 of the drawings, resembled a cumulus cloud, with delicate, deeper markings or fringes within the mass; it showed also patches of lighter color. No. 3 was of a remarkable shape, resembling the outstretched wings of a bird, with shading giving them a solid appearance. As the moon uncovered more of its stem, markings of a twisted form became visible, together with a smaller projection. It seemed as if gases had been ejected, had reached their highest point, and had commenced to sink. No. 4 showed the form of a gas-flame; its outlines were composed of straight lines, and the central jet appeared of the sharpness of a needle. Its surface seemed flat, as if gas was issuing through a narrow longitudinal slit, having three wider openings. With the exception of a slight, yet distinct, quivering, especially in form No. 3, no motion was noticed in these objects. Prominence No. 4 was perhaps the most recent, next No. 3, and last No. 1, in which the gases had already fully spread out.

The prominences on the eastern limb I did not sketch, as my eyes were somewhat affected by the long use of the telescope, and required over half a minute before I was able to clearly note the appearance of the corona, and take a look at the heavens and landscape in general. When returning to the telescope I occupied myself with the above sketches. In the region of the heavens between northwest and northeast, there appeared a tolerably well defined line of separation of color about 15° above the horizon, and, as I am informed, extending all around the southern horizon; above this line the dark-bluish, threatening tint of the sky, and below it a dirty yellow tint, very strongly marked;* here we evidently see through the entire width of the shadow, and the good definition of this chromatic portion of an almucantar would seem to deserve more attention. The landscape had much the appearance of being lit by the full moon, with the addition of a greenish coloring, which gave it a peculiarity distinct from that of a moon-light night; the darkness was not so great as to interfere with coarse writing, or the reading of large type; we used no artificial light, though provided for in case of need. Personally, I only noticed Mercury and Venus, but I only scrutinized the region close to the moon. Not to make this report of too great length, I only communicate the results of the solar-spot observations.

* This tint is well reproduced in the Astronomical Observations made at the Edinburgh Observatory, vol. xi, for 1849–54, Plate 7.

Positions of the principal solar spots observed August 7, near 11½ a. m.

[The measures refer to 8h. 37m. 31s.6 Springfield sidereal time, and the spots are laid down on the accompanying diagram from the tabular quantities. (Plate No. 25, Fig. 11.) The distances are expressed in parts of the solar radius.]

Number of spot.	Position-angle.	Distance from center.
	° ′	
4	229 09	0.660
4 a	232 00	0.627
5	165 52	0.596
6	159 44	0.645
7	80 42	0.417
8	83 25	0.501
9	86 32	0.958

The occultation of spot No. 4 was observed more particularly, and the times will probably also be obtained from the photographs, from which the values of the lunar diameter may be deduced. The position for No. 4 is more conveniently expressed in difference of right ascension ($\Delta\alpha$) and difference of declination ($\Delta\delta$) between the sun's center and spot.* I find—

	h. m. s.		′ ″	′ ″
August 3 (a. m.), from 3 sets at	8 18 16,	Springfield sidereal time,	$\Delta\alpha = +$ 4 19	$\Delta\delta = -9$ 23
August 7 (a. m.), from 5 sets at	8 37 32,	Springfield sidereal time,	− 7 52	−6 49
August 8 (p. m.), from 3 sets at	13 14 48,	Springfield sidereal time,	−11 00	−5 46

The following meteorological observations were made by Mr. Timothy Dudley, of Loami, Illinois:

The thermometers were suspended in the shade at the eastern side of the observatory. The aneroid readings can only be regarded as differential values. He adds the following notes: To 13h 50m, atmosphere of a grayish blue; to 14h 12m, Mercury, Venus, and Mars visible at totality. During totality the horizon, both north and south of the place of observation, was of a beautiful bright orange color, and continued for nearly three minutes.

Sidereal time.	Temp. in shade.	Temp., wet bulb.	Atmospheric pressure.	Wind—Direction and force.	Remarks.
h. m.	°	°	in.		
13 00	73	61.5	29.52	N. E. 2	
10	73	62	.52	N. E. 2	Eclipse begins.
20	72	62	.50	N. E. 2	
30	72	61.5	.50	N. E. 2	
40	71	61	.50	N. E. 1	
50	70	59.5	.50	N. E. 1	
14 00	69	59	.50	N. E. 1	
10	67	59	.50	N. E. 1	Totality.
20	65	60	.47	N. E. 1	
30	66	60	.45	N. E. 1	
40	67	60	.45	N. E. 1	
50	66	61	.45	N. E. 1	
15 00	67	62	.45	N. E. 1	
10	67	61	.45	N. E. 1	Eclipse ends.
20	66	60	.45	N. E. 1	

The number 1 in the column of wind indicates a very light breeze, and 2 a gentle breeze. After 9h no cloud was noticed. The direct effect of the eclipse on the temperature of the air in the shade was a depression of nearly 5°; the wet-bulb thermometer was depressed about 1°; the atmospheric pressure was not notably affected, and a gentle breeze at the beginning of the eclipse changed into a very light one toward its end, preserving its direction from the northeast.

* To change the co-ordinates into heliographic latitude and longitude, I have assumed $I = 7° 15'$ (inclination of ☉'s equator to ecliptic) and ☊ $= 73° 30'$ (longitude of ascending node of ☉'s equator), and find for the three dates—

	° ′		° ′
Heliographic latitude,	−25 55	Heliographic longitude,	211 34
	−26 39		266 47
	−26 16		282 41

The report of Professor J. M. Peirce and one by Mr. J. B. Warner, giving an account of the observations taken at Bloomington, Illinois, are appended. The position of Bloomington I find from the sectional map of Illinois to be 41′ north and 40′ east of Springfield State-house; hence the latitude is 40° 29′, and the longitude 88° 59′ west of Greenwich. The line of 2^m duration of totality, as drawn on the map, passes through this place. The reports by Messrs. R. A. McLeod, E. P. Seaver, and C. N. Fay are likewise appended.

The substance of the above report is made up from notes made during the eclipse and from impressions recorded after the close of the transit-observations on August 7.

I remain, sir, yours, very respectfully,

CHAS. A. SCHOTT,
Assistant, United States Coast Survey.

Professor BENJAMIN PEIRCE, L. L. D.,
Superintendent United States Coast Survey.

NOTE.—In order to insure uniformity in treatment for the better comparison of partial and final results, the measures and discussion of the eclipse-photographs taken at Springfield, Illinois, will be made to conform to the measures and discussion adopted for the Shelbyville pictures, according to the method developed for that station by Mr. Charles S. Peirce. The results for Springfield will be communicated with those for Shelbyville.

REPORTS OF GENTLEMEN ATTACHED TO THE SPRINGFIELD PARTY

Report of Professor J. M. Peirce.

SPRINGFIELD, ILLINOIS, *August* 9, 1869.

SIR: I left this place on the 7th instant, accompanied by Mr. J. B. Warner, for the purpose of observing the solar eclipse at Bloomington.

We arrived there about half past two in the afternoon, and, after a necessarily hasty reconnaissance, selected the platform on the roof of the new store-house of the Chicago and Alton Railroad, as a position easily identified, and in other respects well suited to our purposes. The building is of stone, now unfinished, on the west of the track, and just north of the machine-shops belonging to the road. We were assisted in securing possession of this platform by John A. Jackman, esq., superintendent of machinery of the Chicago and Alton Railroad, to whom we are indebted for various kind offices in our behalf. We were provided with a binocular marine-glass belonging to the Coast Survey. This was attached to the west balustrade of the platform. Mr. Warner had also a good opera-glass with dark screens. Our chronometer was Parkinson & Frodsham No. 1411. We had, also, a stop-watch.

In the observation of the several contacts, and of most of the other phenomena of the eclipse, I used the glass, while Mr. Warner read the chronometer and noted the time at my call. The chronometer was at first read audibly, and both Mr. Warner and myself noted the instant of my first call (at the beginning of the eclipse), but it was afterward judged best to leave the estimate of the time wholly to Mr. Warner.

We were instructed that the principal object of our observations was to determine the times of inner contact. We obtained them as follows: First inner contact, $12^h\ 32^m\ 19^s.9$; second inner contact, $12^h\ 34^m\ 16^s.0$; giving for the duration of totality, $1^m\ 56^s.1$.

Mr. Warner felt great confidence in the accuracy of his estimate of both these times as given by my call. I believe that the latter of the two observations may be relied on as very accurate. In the former case, I think my call was half a second late, but two bystanders, hearing me express this opinion, declared that I had spoken "full early."

Mr. Jackman held the stop-watch during the total phase, starting it and stopping it at my call. The indication of the duration was $1^m\ 56^s.8$ or $56^s.9$. The estimated correction for the error in stopping this watch is $-0^s.5$.

I was unable to make accurate determinations of the times of outer contact. My calls indicated them as follows: First outer contact, $11^h\ 31^m\ 53^s.5$; second outer contact, $13^h\ 29^m\ 40^s.5$; giving for the duration of eclipse, $1^h\ 57^m\ 47^s.0$. The former of these times is probably 10^s too late. I suspected the indentation in the sun's limb at the call of 48^s, and I believe that it existed several seconds earlier. This determination was made almost immediately after we had got our glass and chronometer into their positions, and before I was able to arrange myself in a convenient attitude. The end of the eclipse may have taken place at $13^h\ 29^m\ 19^s.5$ when I first called it. The recorded time indicates the moment at which the tremulousness of the sun's limb appeared to cease.

One large solar spot, near the lower limb of the sun, was visible with my glass. This spot was bisected by the moon's advanced limb at $11^h\ 53^m\ 53^s.9$ and by the following limb at $12^h\ 49^m\ 00^s.0$.

We took note of a few general phenomena, to which it may be proper to refer, without ascribing to them scientific value. Six minutes after the beginning of the eclipse (at $11^h\ 38^m$), I thought that the moon's limb could be traced beyond the sun. At a later time this observation was doubted, but it was again made 22^m before totality (at $12^h\ 10^m$), and again 20^m after totality (at $12^h\ 54^m$).

Eighteen minutes before totality (at $12^h\ 14^m$), the truncation of the cusps, especially of the lower cusp, was pointed out by Mr. Warner. This was afterward seen by both of us to be more apparent with the feeble glass than with the stronger.

Twelve minutes before totality (at $12^h\ 20^m$), the light on the landscape seemed ghastly and of a bluish-green color; but, at $12^h\ 30^m$, it had become yellow and resembled unnaturally brilliant moon-light. The shadows were strongly defined, and the whole landscape presented a remarkable and beautiful aspect. In casually glancing at the bystanders, I was struck by the pallor of their faces, but I have not noted at which of the two times just mentioned I observed this phenomenon.

The total phase came on with startling suddenness, and the end of totality was likewise marked by an instantaneous change in sky and landscape. But I was unable to see the limit of the shadow moving over the ground.

During totality, the sky was of a violet blue above, while it was lurid near the horizon, at any rate, in the north. The spectacle was of an indescribable beauty, and one for which the mind was by no means prepared by the more and more rapid succession of aspects preceding the period of complete obscuration. The moon had not to my eye the spherical look which is ascribed to it in some accounts of total eclipses. It resembled rather a black, jagged wafer, a portentous blot in the midst of the brightness of the corona.

The corona impressed me as distinctly cruciform, the principal projections occurring near the north, south, east, and west points. But these projections had not the character of rays, such as are seen in the phenomenon called "the sun drawing water," but were irregularly curled, the whole resembling somewhat the corona occasionally seen in the aurora borealis. The light of the corona seemed to me pearly white, but Mr. Warner thought it had a warmer color.

We saw two protuberances, which I noted as gold-colored. We marked these independently in nearly the same places, that is, at about 190° and 260° from the vertex (counting through east and south). We had no means of making measurements of the corona and the protuberances.

Thirteen minutes after totality (at $12^h\ 47^m$), Venus was still seen by a bystander.

At the beginning of the eclipse, the wind blew freshly from the east, and was quite troublesome to us in our exposed position. But 18^m after totality (at $12^h\ 52^m$), we noticed that it had entirely died away, and we thought that this change had taken place some 20^m before totality.

I was provided with two sets of screens, one of a very deep green, and a lighter one of red; but I found it impossible to use the lighter glass at any time during the eclipse. The attempt to use it just before the beginning of totality disconcerted me and caused the already-mentioned doubt of the accuracy of my observation of the first inner contact. The total phase was observed without a screen.

All which is respectfully submitted.

J. M. PEIRCE.

CHARLES A. SCHOTT, Esq.,
Assistant in the United States Coast Survey.

Report of Mr. J. B. Warner.

SPRINGFIELD, ILLINOIS, *August* 9. 1869.

SIR: I was directed to accompany Professor J. M. Peirce to Bloomington for the purpose of assisting in observations on the total eclipse of August 7, and accordingly left this place at noon on the day of the eclipse.

I was instructed to note with a chronometer the times of contact, and to notice such other phenomena as I had opportunity to observe.

The times, as I observed them, have been communicated to Professor J. M. Peirce, who reports to you. I think that they were obtained with considerable accuracy, particularly the time of the second inner contact, which I was able to get with precision. The difference of $0^s.7$ or $0^s.8$ in the estimates of the duration of totality, as observed by the stop-watch and the chronometer, is, I think, to a great degree, to be accounted for by the imperfection of the former instrument, which had been observed before this occasion to mark an error of at least $0^s.5$.

The general effects of the eclipse were extremely grand and impressive, and from our elevated position could be well observed. I was provided only with an opera-glass, and this I used but seldom.

There was little change in the light during the half-hour after the first contact, but objects began to assume a somewhat greenish and very gloomy hue; and, during the five minutes immediately before the second contact, the light was very weird and strange, giving an unearthly hue to the landscape as it lay outstretched beneath us. The shadows had the cold, unreal appearance of moon-shadows, and the whole effect on the mind was chilling.

The cusps of the sun, especially the lower one, appeared truncated. My glass was not of sufficient power to show the edge of the moon serrated, nor did it bring out at all the dark limb of the moon. About a minute and a half before the second contact, Venus appeared, and Mercury soon followed.

On the instant when the last ray of light was intercepted, the country assumed a hue yet more strange and awful, and it was impossible to prevent a sort of dread from seizing on the mind.

The black disk of the moon appeared edged with a silver rim of great brilliancy, which was within the corona and far excelled it in brightness. The corona seemed to me of a whitish, perhaps slightly green, color; and had a rolling, curling motion like smoke. Streamers issued from it in several directions, but my attention was principally held by the waving band slightly west of the vertex, which seemed to me to be most active and conspicuous, and which waved toward the vertex. I cannot tell how many of these streamers there were, or what their arrangement was. On first looking up from the chronometer, my eye was taken with two very bright projections from the black disk, which seemed of an orange color. The largest of these was at about 170° (toward the right) from the vertex; the smaller at about 100°.

I had been provided with a chart of the stars in the vicinity of the sun but was too much occupied with the corona to search for them. I noticed, however, that Regulus did not shine out, as I had expected, between Venus and the sun. The darkness was not deep, and I think that I could have dispensed with the lighted lantern which stood by the chronometer. Before the light had become faint I had fixed on a new unpainted shed, which was about thirty-five rods distant, and I found that I could descry its yellow shingles during the total phase.

Along the southern horizon there lay what seemed a cloud (though no cloud was perceptible in the sky before or after totality), colored bright orange, stretching away toward the east).

The town below us was perfectly quiet during the darkness, though very noisy immediately before and after. Venus continued to shine brightly after the sun had re-appeared, and was watched for thirteen minutes by bystanders. The phenomena of the departure of the moon were similar to those of its approach.

We were informed by people of the town that a very peculiar doubling of shadows had been observed just before and after the total phase when the sun was reduced to a crescent, but these we had no opportunity to observe.

As I could allow my attention to be diverted from the chronometer only a minute and a half, I had no opportunity to make many or accurate observations.

Respectfully,

JOSEPH B. WARNER.

CHARLES A. SCHOTT, Esq.,
Assistant in the United States Coast Survey.

Report of Mr. E. P. Seaver.

SPRINGFIELD, ILLINOIS, *August* 7, 1869.

SIR: I have respectfully to report the following observations made by me during the total eclipse of the sun, August 7, 1869, at Springfield, Illinois:

1. The instrument used by me was a reconnoitering-telescope, C. S. No. 4, mounted equatorially, and provided with a camera.

2. The disk of the sun projected upon the screen was $4\frac{3}{4}$ inches in diameter, and displayed several distinctly-marked solar spots, which were designated by the numbers 4, 4*a*, 5, 6, 7, $7\frac{1}{2}$, 8, and 9. Numbers 4 and 9 were much larger than the others, and exhibited well-defined umbræ and penumbræ. The others appeared to be about as large as dots made by a common lead-pencil on the screen, and their contacts with the limb of the moon could be noted with great accuracy, but their re-appearances could not be so well ascertained, and only two were noted.

3. The first external contact of the sun and moon was noticed at $4^h\ 55^m\ 28^s$;* but the actual contact must have occurred some seconds earlier, for there was a decided indentation of the sun's limb before I was sure of the fact of contact. This delay arose partly from the inherent difficulty of observing soon enough such a contact and partly from the fact that the contact actually occurred at a point on the sun's disk about 30° from where I had expected to see it. Judging from my subsequent observation of the rate of progress of the moon's limb over the sun's disk, I am certain that 6^s should be subtracted from the time given above, and that the time of actual contact was $4^h\ 55^m\ 22^s$.

4. Contact of 4*a* occurred at $5^h\ 19^m\ 20^s$. The *first* of the three minute spots which composed 4*a* was the one observed.

5. Contact of the umbra of 4 occurred at $5^h\ 19^m\ 43^s.5$. Disappearance of the umbra of 4 occurred at $5^h\ 20^m\ 21^s.5$.

6. As the spot 4 approached the limb of the moon, it seemed to grow fainter, and, between the two epochs noted above, it gradually melted away, so that the disappearance was not well defined, and the observation was not very satisfactory.

7. Contact of spot 7 occurred at $5^h\ 36^m\ 19^s.5$. This was not a very satisfactory observation.

8. Contact of spot $7\frac{1}{2}$ occurred at $5^h\ 37^m\ 43^s$. This was a satisfactory observation. This spot was much more clearly defined than it had been in the forenoon.

9. Contact of spot 8 occurred at $5^h\ 39^m\ 20^s.5$. Satisfactory.

10. At $5^h\ 46^m$ shadows were defined on the grass with startling distinctness. The light was of a hard, cold, gray-blue color. The air felt decidedly chilly.

11. At $5^h\ 50^m\ 50^s$ the lower cusp of the sun's disk appeared to be forming a bead in a manner resembling a drop of water forming at the end of a straw. This phenomenon lasted about 20^s. I did not notice it again, though I looked for it frequently.

12. Spot 9 bisected, as shown in the figure, by the moon's limb at $5^h\ 53^m\ 52^s.5$. The figure also shows acurately the form of the penumbra of 9 at this moment. It was well defined.

13. Beginning of the total phase occurred at $5^h\ 55^m\ 56^s.5$.

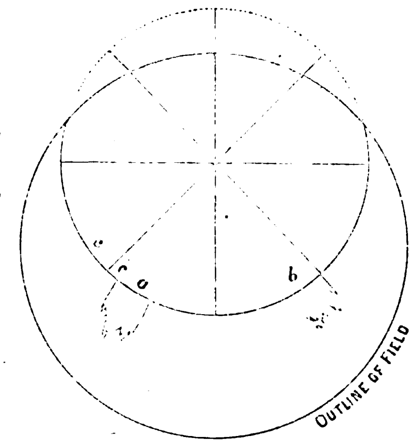
14. As the crescent grew very thin, beads began to form at each end, little black lines with sharp ends apparently shooting from the moon's disk in a radial direction across the thin crescent and chopping it into beads. At last the crescent was reduced to a string of beads about an inch and a half long, which trembled for an instant and then suddenly disappeared. The disk of the moon was faintly irradiated near the beads while they were visible, and for a time (I should say 15^s) after they disappeared. The beads were not globular, but diamond-shaped, from an apparent adhesion to each other and to the limbs of the sun and moon. They were exceedingly bright, particularly at the points of adhesion.

* All the times noted were by chronometer Dent 2171.

15. I now glanced upward to the corona, which appeared silvery white. In the southern horizon I saw a bright-yellow sky shading downward to a deep orange and copper color. I had noticed previously that the horizon in this quarter was of a deep blue, almost black. The stars flashed out with extraordinary brilliancy.

16. Returning to my camera, I noticed that the whole moon's disk on the screen was faintly irradiated, the irradiation increasing in intensity toward the edge of the disk, which was so bright and sharply defined as to enable me to keep the point of the approaching contact well in the center of the field during the total phase. As the instant of contact approached, the edge of th moon's disk grew brighter and brighter, and finally was all aglow. (See sketch.)

17. During the total phase two rather bright patches of light appeared an the screen. They were first noticed early in the phase and lasted till the re-appearance of the sun's disk. Their forms and relative situations are approximately given in the sketch. They are marked *a* and *b*.



Sketch showing the appearance of the moon's following limb about 30ˢ before the end of the total phase. The re-appearance took place at *c c*. The bright patches of light were at *a* and *b*.

18. Suddenly, at 5ʰ 58ᵐ 43ˢ.5, appeared a beautiful string of beads (at *c c* in the sketch), similar to those already described, but brighter. The irradiation and bright patches of light, just described, disappeared at the same instant. The beads trembled for an instant and then melted into a thin streak of light with beads at the ends. When the crescent had appeared around 50° of the sun's disk, no more beads appeared on the cusps.

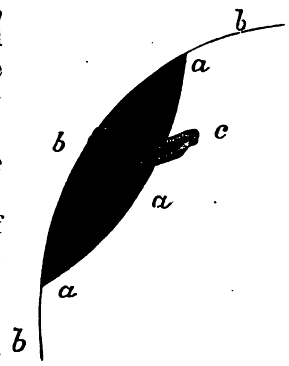
19. Glancing at the southern horizon, after making the record of time above, I saw that the sky there had changed again to a deep blue.

20. At 6ʰ 18ᵐ I noticed that the exterior edge of the penumbra of spot 4 was much more sharply defined than it was before its disappearance. The re-appearance of this spot was not noted.

21. At 6ʰ 33ᵐ 30ˢ (about) spot 6 re-appearead.

22. At 6ʰ 37ᵐ 59ˢ spot 8 re-appeared *distinctly*. I judge that it was bisected by the moon's limb 2ˢ earlier.

23. At 6ʰ 49ᵐ 40ˢ.5 spot 9 appeared bisected by the moon's limb, as shown in the figure. The figure also shows the *shape of the penumbra* as it appeared a few minutes later, the shape having changed during observation.



a a a, moon's disk; *b b b*, sun's disk; *c*, spot 9.

24. The end of the eclipse was satisfactorily observed at 6ʰ 54ᵐ 7ˢ.5.

E. P. SEAVER.

C. A. SCHOTT, *Assistant Coast Survey,*
In charge of Astronomical Station, Springfield, Illinois.

Report of Mr. R. A. McLeod.

AUGUST 8, 1869.

SIR: The instrument with which I observed the solar eclipse of August 7 was a binocular marine-glass, magnifying two and one-half times. It was furnished with red shade-glasses so dark that the features of the landscape were invisible through them on a bright day. The power of the glass was such that in looking with it at the largest spot on the sun, on the day of the eclipse and two days before, the shape of the spot was distinctly defined, but the smaller spots were not discernible. The instrument was secured to a firm stand, and had movement in altitude and azimuth.

I had been directed, in estimating lengths, to take the sun's diameter as a unit.

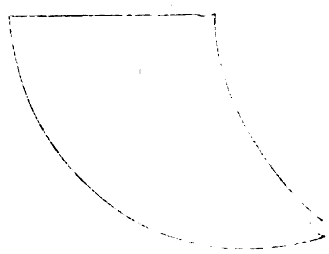
At 4ʰ 55ᵐ 21ˢ, by chronometer Dent 2171, I observed the first outer contact. It was instantaneous, but occurred at a point from 5° to 10° higher than where I had expected it. Immediately

before the contact I noticed no agitation of the sun's limb, nor could I perceive at all the approaching moon.

During the progress of the eclipse the large spot near the sun's lower limb seemed at some times much darker and more distinctly defined than at others, but I made no accurate observations upon it.

At 4^h 30^m, Springfield mean time, the upper cusp appeared distorted.

At 4^h 35^m, Springfield mean time, the blue of the sky overhead had become perceptibly darker, while along the east horizon the tint seemed unusually light.



At 4^h 38^m, Springfield mean time, the lower cusp appeared as in accompanying figure.

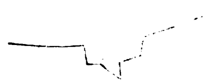
At 4^h 55^m, Springfield mean time, the sky on the western horizon was of a very light azure, but the color deepened gradually as the eye followed it up toward the zenith, where the blue was ntense. The shadows of objects near me, as thrown on the ground, were peculiarly soft. The water of a pond near by looked very black. The woods, 400 or 500 yards distant, presented a singular appearance. Beneath them the gloom was strikingly deep, while the tree tops seemed of a lighter green than usual. The sun's light had a bluish tint, making the faces of those who were near me appear ghastly. The general effect of the light suggested that produced by bright moon-light.

I observed the extinction of the last solar ray at 5^h 55^m $55\frac{1}{2}^s$, by chronometer, one portion of the crescent being separated from the rest by a dark line. It then broke up into small fragments, which disappeared quickly, one after the other, the lowest *one* going first, and the final extinction being somewhat above the center of the line of beads as at first seen.

Up to the time of total immersion I had not seen the preceding limb of the moon, but the next instant I perceived its jagged edge in relief against a faint red glow surrounding it. The glow grew brighter every moment, and soon appeared as a band all around the moon. I at once removed my shade-glasses and saw the same aspect of the moon for an instant with my naked eye. Upon returning my eyes to the glass I found the corona and the accompanying rays already visible in all their brilliancy. (Plate No. 25, Fig, 12). It is from a sketch roughly made, perhaps 10 seconds after my first sight of this beautiful phenomenon.

At this moment the corona was brightest on the upper part of the following side, in the space between two points, 30° and 80° from the vertex. D and E in Fig 12 represent what looked like two mountains of light, being apparently portions of the corona itself, not differing from the rest of it at all in color, but being much brighter. D and E were entirely unlike the protuberances in appearance. The corona's width in this part appeared to be about $\frac{1}{16}$, but this estimate is quite uncertain, as I could perceive no sharply-defined exterior limit to the corona; but, from an intense brilliancy close to the moon's edge, it gradually softened away into faint fringe-like rays. The color of the corona, where it was brightest, was pure white, but its dimmer portions partook of a golden tinge. I remarked, about a minute later, that the corona's brightness on the following side had diminished.

At the time of my sketch only three protuberances were visible. Their estimated distances from the vertex were, A, 175°; B, 115°; C, 100°. Of these, A was by far the largest, and its shape was very decided to my eye. I was struck by its *solid* appearance. It looked not like a flat jet of flame, but like a solid conical body. Its length was about one-eighth, and it was of a rosy color. I did not notice B and C with much care, but observed the contrast of their pale rosy tint with the white of the corona. One of them had the shape given in the annexed figure, but which one I omitted to record, and cannot say with certainty. I did not notice the appearance afterward of any protuberances on the preceding side, my attention being diverted to other features.



From the outer rim of the corona, bright white rays emanated on every side, but their length was greatest in four directions, as represented in Fig. 12. The four *arms* of rays were of unequal length, F being by far the longest, G the shortest, and H and I of about equal length. I took especial pains to estimate the length of F, and could trace it to the distance of nearly two

diameters of the moon. The angle of the axis of F with the vertical was about 20°. This angle did not change with a slight motion of my glass. The end of the longest ray was slightly curved toward the vertical.

During the total phase, I noticed several flashes or tremors of light across the corona, apparently in a radial direction from the center out. The moon did not present that inky blackness which I had expected to see, but was much lighter. Glancing for a moment at the landscape, I found that the darkness was much less than that of a starlight night. The appearance of the sky was as if a blackish-blue hemispherical cover were hanging down from overhead, its rim reaching to within about 12° of the horizon. Between this rim and the horizon, to the north and as far around as I looked, the sky was of a dusky yellow.

Shortly before the end of the totality, the corona and rays had faded away from the preceding limb of the moon, on which my attention was now fixed.

At $5^h\ 58^m\ 4\frac{1}{2}^s$, by chronometer, a red band became visible around that limb, crossed here and there by dark lines, which were continually changing their position. One line did not seem to undergo any change except to grow broader and darker as the moment of emersion approached. It was very near the point where the sun re-appeared.

I observed the second inner contact at $5^h\ 58^m\ 43\frac{1}{2}^s$, by chronometer. The sun's re-appearance seemed more sudden to my unprotected eye than his disappearance had seemed, viewed through the shade-glasses.

The effects on the landscape produced by the increasing light as the moon passed off the sun's disk were by no means so striking as those produced before the totality by the diminishing light. This fact was doubtless owing to the different condition of my eyes in the two cases.

I observed the second outer contact at $6^h\ 54^m\ 7\frac{1}{2}^s$, by chronometer.

Respectfully,

ROBERT A. McLEOD.

Mr. CHARLES A. SCHOTT.

NOTE.—In regard to the distortions of the cusps, it should be borne in mind that the appearances which I observed and have sketched were those presented to my eye by a comparatively weak and very darkly-shaded glass. I have since that time seen photographic pictures taken at various stages of the eclipse, and, in perhaps every case, the cusps are sharp and undistorted. Observers, also, with powerful glasses, have perceived no distortion. On the other hand, the distortions have been quite uniformly seen by observers with simple opera-glasses. My own attention was first called to the appearance given on page 158, upper figure, by Mr. Montague, who was looking at the time through a small transit-instrument.

The explanation of these facts is perhaps as follows: The sun's disk, as is well known, presents to us a surface, the brightness of which is by no means the same in every part, and the difference in brightness of adjacent parts is, as in the case of the *faculæ*, most perceptible near the edge of the visible disk. Accordingly, during the progress of an eclipse, a cusp, retreating along the rim of the disk, frequently reaches points where the inequality of the solar light for small adjacent portions of the disk is very great. The dark body of the moon on one side of the narrow strip of the crescent near the cusp, and empty space, on the other, shield the eye from the usual glare, and enable it to appreciate the peculiarities of the strip. Under these circumstances, it is only the brightest portions of the strip (the tops, probably, of the waves of the luminous solar envelope) which emit enough light to be visible through glasses of small size or furnished with very dark shade-glasses, the darker portions (the hollows, probably, between the waves) appearing black; while the sensitive paper in the camera, or the eye of an observer who looks through a powerful glass or through one lightly shaded, receives light from the darker as well as the brighter portions of the strip, and sees the outlines of the cusp complete. Accordingly, accurate observations of the distortions of the cusps might give interesting information in regard to the shape of the surface of the luminous solar envelope.

Perhaps a similar explanation may be given of the very different shapes of the same solar protuberances as seen through different glasses. The outlines given by weak glasses are probably the outlines of the densest and most luminous parts, while those given by glasses of higher power inclose also a certain portion of the more rarified gaseous matter surrounding the inner and denser part—the size of the portion increasing with the power of the glass. A comparison of the shapes given by different glasses may, therefore, show the comparative densities of different portions of the protuberance.

NOTE 2.—Of six gentlemen, all of perfect vision, who experimented, during the totality, with cards prepared for the purpose, three could read distinctly *Diamond* type; one nothing smaller than *Pearl;* one nothing smaller than *Nonpareil;* and one nothing smaller than *Bourgeois.*

Report of C. N. Fay, aid in observing eclipse of August 7, 1869, *at Springfield, Illinois.*

I arrived in Springfield on Wednesday, the 4th, at 6 p. m. From Wednesday to Saturday I spent the time in visiting the station and in making preparations. I succeeded in borrowing a seven-foot refractor, with two inches aperture, from Mr. Watson, of this place, who was the maker, and is an amateur observer. On Saturday I set up this instrument, and also a transit-instrument borrowed from the city-surveyor. I set up for them a seat and rest sufficient to accommodate two persons.

At 4^h 50^m, Washington mean time, the time-keeper began to call. I used the small transit just mentioned. With this instrument of about one inch aperture and ten inches focal length, magnifying some twenty diameters, I saw the first contact at 4^h 55^m $18^s.3$.* I suspected the contact at least one second before recording it. I saw no limb of the moon before the contact. I saw no disturbance of the sun's limb before contact. After contact I left the transit-instrument in order to adjust the refractor above mentioned. I observed the cusps with this refractor and also with the transit. I had my attention called to the irregularity in the lower cusp, but I failed to see it. I noticed no agitation in the cusps. I noticed the light at about 5^h 40^m; it was sickly, and, in effect, resembled a yellow moon-light. The sky was turning gray. At 5^h 50^m I took the refractor to observe the second contact. I saw the formation of Baily's beads running from the top downward; the beads were more crowded at the top. Totality followed at 5^h 55^m 58^s by Dent 2171, showing nearly Washington mean time. I think this observation at least three seconds slow, as the glow on the limb of the moon was deceptive. My pencil broke while recording this, and the remaining phenomena of totality were noted immediately after from memory. I stopped to take off glasses; the corona appeared in the interval. I saw the protuberances as in diagrams; with my naked eye I also saw them. I saw no appearance of streaks on the preceding limb just before totality. The corona was brightest at the quadrants counting from the vertex. Streaks or rays *reached* the *limb of the moon* in the intervals of these quadrants. The protuberances were at first seen on the following limb, then they disappeared behind the moon's limb, and others appeared on the preceding limb. The color of the corona was that of the electric spark in hydrogen. I say no Baily's beads at the end of totality. I observed the end of totality at 5^h 58^m $42^s.5$ by chronometer. I did not look away from the glass except at times already mentioned. I observed the final contact, also, with refractor, at 6^h 54^m $08^s.5$ by chronometer.

CHARLES N. FAY.

REMARKS—Just before totality I thought I saw a continuation of the upper limb of the moon. It was probably owing to instrumental imperfection. I saw one or two flashes across the field before totality. As they traversed the whole field I inferred that they were the effects of nervous fatigue.

As to the protuberances, I am unable to give a more definite form to them, but I have thought since the eclipse that, taking down their positions from memory as I did, I interchanged the

---

*By chronometer Dent 2171.

"wings" with another protuberance; that is, the "wings" should be at the upper side of the horizontal diameter instead of below it, and rather nearer to it than the protuberance originally placed there. The annexed diagram (Plate No. 25, Fig. 14) shows the position I propose. The dotted lines in my sketch connect the old positions of the protuberances A and B with the corrected positions A′ and B′.

Reports of Professor A. C. Twining, Mr. George T. Carter, and Mr. Benjamin Aycrigg.

Professor A. C. Twining reports some observations which he made with the naked eye, at Springfield, Illinois. Ten minutes before the total obscuration began, he noticed, low down in the western horizon, a pale twilight. At 5^h 1^m of true local time, Venus was first seen. After the totality commenced, an attempt was made, but unsuccessfully, to discover traces of the zodiacal light. Vertically below the moon's center, a copper-colored protuberance appeared, which was judged to have an apparent length of about one-tenth of the moon's diameter, with a breadth only seven-tenths as large as the length. The projection of the moon's shadow on the upper atmosphere was perceptible, bringing to view long, thin streaks of cirrus clouds, which were invisible by ordinary daylight. Venus was steadily visible until 5^h 19^m, and, with brief intermissions, until 5^h 29^m. Mr. Twining also furnishes the following observation, made with the naked eye, by Rev. Charles H. Marshall, at Mattoon, Illinois: "The moment before total obscuration, beads of light appeared in great brillancy, apparently about six in number, differing in size, and equally distributed over one-eighth of the sun's disk. These beads were much brighter than the prominences, flashing for an instant upon the sight, and then vanishing."

Mr. George T. Carter has recorded the following observations made by him at Springfield, Illinois, when the sun was within about ten minutes of total obscuration:

Standing at the top of an embankment, about 20 or 25 feet in height, with his back to the sun, he observed that his own shadow, cast at the foot of the embankment, had a sharp outline on its southern edge, while the opposite edge was fringed and blurred, as if produced by two or more illuminating points. The blurred portion of the shadow was about four or five inches wide. The shadows of smaller objects, received at shorter distances, exhibited similar peculiarities. The phenomenon became more and more distinct as the moment of total obscuration approached. The same difference was noticed between the upper and lower edges of the shadows, the upper edge showing the sharp outline. At your suggestion, Mr. Carter has experimented with two lights of unequal brightness, and seen the combined shadows of a body exposed to them, surrounded by a penumbra of variable brightness, as might have been anticipated. Mr. Carter concludes, therefore, that the small uneclipsed portion of the sun supplied the brighter light, and the protuberances on the eclipsed edges, the fainter light. Under these two sources of light, the penumbra of objects might be imperceptible on one side of their shadows and distinctly pronounced on the opposite side.

Mr. Benjamin Aycrigg observed the eclipse near New Albany, Indiana, within the area of totality. He describes the corona as extending to a distance equal to one-eighth or one-tenth of the sun's diameter; its exterior being a wavy and ill-defined circle. Its color was bluish-white. Streaks of light extended in the direction of certain radii of the sun prolonged; that is, in the plane of the ecliptic and the rectangular plane. These streaks had a length equal to three-quarters of the diameter of the sun. On account of the flashes seen in some of these streaks, Mr. Aycrigg thought that they did not belong to the sun, but were auroral streamers in the earth's atmosphere, made visible by the withdrawal of the sun-light during the eclipse. Mercury, Venus, and some of the bright stars, and also the red flame projecting beyond the moon, were distinctly seen.

Observations at Hanover College, Indiana.

The station selected for observing the eclipse was in the College Campus, south of the college-building, from which the hills south of the Ohio River, for eighteen miles, were in full view, and the most prominent points of the north bank for the same extent, for a view of a still wider region of scenery, and, as the best position for observing the sweep of the shadow, the cupola of the building was occupied.

The morning of Saturday was employed by the observers in placing their instruments and completing their arrangements. The night previous, observations had been made for the purpose of correcting their time. The records of the barometer and thermometer were begun at 2 o'clock p. m., Saturday.

The instruments in use were a standard thermometer; a first-class aneroid barometer, adjusted to a standard mercurial barometer; three refracting telescopes, viz, one three-inch aperture, equatorially mounted, one two and a half-inch aperture, on altitude and azimuth stand, one two-inch aperture, on altitude and azimuth stand.

The astronomical corps consisted of the following gentlemen: S. H. Thomson, in charge of the two-inch refractor; J. H. Thomson, in charge of the two-and-a-half-inch refractor; O. Mulvey, in charge of the three-inch equatorial; G. D. Archibald, observing sweep of the shadow; Heber Gill, recorder of observations; H. W. Wiley, recorder of observations; E. H. Allison, recorder of observations; J. C. Eastman, in charge of the time; G. W. Bean, in charge of barometer and thermometer.

The observations recorded are as follows:

Time.	Barometer.	Thermometer	Wind.		Remarks.
			Strength.	Direction	
h. m. s.	in.	°			
2.00 00	29.12	73.00	Breeze	N. E	
2 20 00	29.12	73.25	....do	..do	
2 40 00	29.115	72.75	....do	..do	
3 00 00	29.127	73.00	....do	..do	
3 20 00	29.123	74.00	....do	..do	
3 40 00	29.12	73.25	....do	..do	
4 00 00	29.12	73.00	....do	..do	
4 10 00	29.11	73.50	....do	..do	
4 20 00	29.11	73.00	....do	..do	
4 25 45	29.11	73.00	....do	..do	First contact.
4 30 00	29.11	73.00	Light breeze.	..do	
4 36 25	....	....	....	....	Sphericity of moon first noticed on eastern
4 40 00	29 11	73.00	Light breeze.	N. E	limb, which was then observed until the
4 50 00	29 11	72.50	....do	..do	appearance of Baily's beads.
4 53 00	....	....	....	....	By this time there was a perceptible dimi-
5 00 00	29 09	72.00	Light breeze.	N. E	nution in the intensity of the light.
5 02 00	....	....	....	....	A further perceptible reduction of light.
5 09 00	....	....	....	....	Still further perceptible reduction of light.
5 10 00	29 09	71.50	Strong breeze	N. E. E .	
5 20 00	29 09	70.50	Light breeze.	..do	
5 23 00	....	....	....	....	Venus visible; getting darker rapidly.
5 24 44	29 09	70.00	Calm	....	Beginning of totality.
5 26 58	29 07	70.00	Light breeze.	N. E. E .	End of totality.
5 30 00	29 06	70.00	....do	..do	
5 40 00	29 05	69.50	....do	..do	
5 50 00	29 05	69.75	....do	..do	
6 00 00	29 03	69.50	....do	..do	
6 20 00	29 03	69.50	....do	..do	
6 21 05	29 03	69.50	....do	..do	Last contact.

The sky was entirely free from clouds during the whole afternoon, with the slightest possible haze or bluish smoke. Just previous to totality, the sky at the west, below the sun, was reddish yellow, growing more yellow toward the south. During totality to the north and northeast it was quite dark, almost black (seemed opaque, as no stars were visible there); growing lighter toward the southeast. For some time before, and while totality lasted, the faces of bystanders and other light-colored objects had a greenish-yellow color; the leaves looked yellow. After totality objects, generally, just seemed pale, without any color, as though they were lighted with a faint *white* light, the light growing gradually stronger till the end of the eclipse. A number of

persons remarked that the light was stronger just after the close of totality than previous to the beginning of it. This effect was doubtless caused by the pupil of the eye having dilated in the darkness.

Baily's beads were seen only at the cusps, and not in the center of the crescent; those near the extremities being smallest, those more remote seeming elongated; they dropped off in succession very rapidly; there was no distortion of the cusps.

During totality the following heavenly bodies were seen: Mercury, Venus, Saturn, Arcturus, Vega, Antares, Altair, and Benetnasch. Some claim to have seen more, but the above are all that were recognized by the observers.

No bodies were discovered between the sun and Mercury. The sweep of the shadow was distinctly observed; it was first noticed on the river-hills, some two miles below the college, traveling rapidly toward Madison; when totality arrived, the hills back of Madison, about four miles above, were yet in sun-light; in a few seconds they, too, were in darkness. When the shadow returned the Madison hills were again lighted, while the observers were still in the gloom. In a few seconds it swept swiftly by, and down the river for fourteen miles, when it was lost to view on the land, but was visible for several seconds after in the air, sweeping to the southeast.

The flame protuberances were first observed just at the commencement of totality, and at the place of the first inner contact. Just at this moment the excitement was so intense that the observers were slightly thrown off their guard; the time, however, was very carefully noted, though the shapes of the smaller flames were not; but, to the recollection of one observer, they were jagged and almost a continuous chain to the southeastern limb. Some of the flames were plainly visible to the naked eye, though, of course, their shapes were not; the color thought to be of a more reddish purple than rose color by some of the observers; by others, more of a bluish-rose tinge. One flame continued visible for full eight seconds after totality terminated.

From July 27th to the 30th the magnetic needle lost two minutes of variation; since then there has been no change.

OBSERVATIONS AT DES MOINES, IOWA, NEAR CEDAR FALLS, IOWA, AND NEAR SAINT LOUIS, MISSOURI.

The operations under the charge of Assistant J. E. Hilgard comprised the observations of the total eclipse at Des Moines, Iowa, and determinations of the northern and southern limits of totality; the former near Cedar Falls, Iowa, the latter near Saint Louis.

The party at Des Moines consisted of Assistant Hilgard; Assistant Edward Goodfellow; Mr. J. H. Lane, of Washington City; Dr. T. C. Hilgard, of St. Louis; and Lord Sackville A. Cecil, of England. The three former were practiced in observations of time, but Mr. Goodfellow's sight had latterly been affected by over-use, and he was obliged to abstain from using his eyes for some time after the eclipse. Dr. Hilgard's skill in drawing from microscopic observations was looked to for enabling him to furnish more precise delineations of the red protuberances than have usually been obtained.

The weather was stormy, with heavy rains and high winds during the night preceding the eclipse. In the morning it began to clear away, and about noon the sky became almost cloudless; but a faint haze still appeared in the air during the entire afternoon.

Mr. Hilgard observed with an achromatic telescope by Fitz, of 3½ inches aperture, focal length 29 inches, with an erecting eye-piece, giving a magnifying-power of about 40 diameters. The focal adjustment was very carefully made, and the definition exceedingly good. With this telescope the first and last contacts were viewed and noted by Mr. J. E. Hilgard. The first contact was unexpectedly well defined, which was subsequently ascribed to the fact that a considerable projection appeared on the moon's edge, which sensibly indented the sun's disk not far from the point of contact. The last contact was characterized by a peculiar appearance of a rapid diffusion of light along the sun's margin, as of a restoration of liquid equilibrium.

Both interior contacts were viewed by Dr. Hilgard, who had then taken his place at this telescope, which proved to give the best definition, for the purpose of figuring the red flames. The instants of beginning and end of totality were called out by him and noted by the former observer.

The four observations thus obtained are as follows; the times being noted by sidereal chronometer Fletcher 1707, the error and rate of which, deduced below, give the annexed instants in mean time:

	Chronometer.	Mean time.
	h. m. s.	h. m. s.
First contact	14 05 07.5	3 43 06.9
Beginning of totality	15 07 40.5	4 45 29.7
End of totality	15 10 36.0	4 48 24.8
Last contact	16 07 44.5	5 45 24.0

The corrections of the chronometers to local time were obtained by means of telegraphic time-signals sent from Springfield; the party at Des Moines having arrived only on the day preceding the eclipse, and having had no opportunity to make observations of time, on account of clouds and rain. The difference of longitude between Des Moines and Springfield had been ascertained during the preceding spring to be $15^{m}\ 55^{s}.42$ when referred to the eclipse-stations. Applying this reduction, the following exchanges were had:

Date.	Springfield mean time.	Des Moines mean time.	Kessels 1287, sidereal.	No.
	h. m. s.	h. m. s.	h. m. s.	
August 6	9 59 01.70	9 43 06.28	18 46 01.06	14
August 7	10 49 07.60	10 33 12.18	19 40 16.59	7

The following are the comparisons of chronometers:

		h. m. s.	
August 6	Kessels 1287	19 24 50.00	Mean of 6 comparisons.
	Fletcher 1707	20 41 00.44	

Comparisons through a mean-time chronometer.

		h. m. s.	h. m. s.	h. m. s.
August 7	Kessels 1287	8 52 30.0	15 01 40.0	15 01 40.0
	Fletcher 1707	10 08 36.0	16 17 44.3	16 17 44.3

If we deduce the first comparison, on August 7, from the last, by reference to that on August 6, we find a residual of only $0^{s}.1$, assuring us of the good performance of the time-keepers. The rate of the Kessels chronometer in Washington, before the balance was checked for transportation, was $4^{m}\ 00^{s}.9$ on mean time; that of the Fletcher, $3^{m}\ 55^{s}.15$, neither differing much from the rate found at Des Moines.

Mr. Lane observed with Negus 1281, going on mean time, and found by Professor Newcomb to be $6^{h}\ 13^{m}\ 0^{s}.8$ fast of mean time at the station. In the evening of August 7, transit-observations were obtained upon five stars, including δ Ursæ Minoris, with reversal of instrument, when the correction of chronometer Kessels 1287 is found $-7^{s}.45$ on sidereal time, at 18^{h}, with a probable error of $\pm\ 0^{s}.12$. This value carried forward, with the known rate, to $19^{h}\ 40^{m}\ 16^{s}.59$, the showing of Kessels, when compared with the Springfield signals, gives $19^{h}\ 40^{m}\ 08^{s}.87$ for the sidereal time of comparison.

The mean time by the Springfield signals is, as above stated, $10^{h}\ 33^{m}\ 12^{s}.18$, corresponding to $19^{h}\ 40^{m}\ 08^{s}.60$, showing a satisfactory agreement with the result obtained by observations at Des Moines.

Using the above values, the following table shows the observed times of the phases, reduced to Des Moines mean time:

Observer.	First contact.	Totality, I.	Totality, II.	Last contact.
	h. m. s.	h. m. s.	h. m. s.	h. m. s.
J. E. Hilgard	3 43 06.9	4 45 29.7	4 48 24.8	5 45 24.0
E. Goodfellow	3 43 06.3	4 45 28.9	4 48 23.4	5 45 22.8
J. H. Lane	3 43 07.2			5 45 25.2
S. A. Cecil		4 45 27.		5 45 19.

In the above table, Mr. Goodfellow's observed time of beginning of totality has been increased by 5^s, and that of last contact by 10^s; these corrections being considered as due to misreadings of the chronometer.

Sketches taken during totality by Dr. T. C. Hilgard (Figs. 1 and 2, on Plate No. 26) represent the sketches made of the crimson flames, and in Fig. 3 is reproduced a very detailed sketch of the large protuberance, which, in minuteness of representation, excels all others that had hitherto been obtained. Dr. Hilgard describes it in these words: "The appearance of lowest protuberance was that of a cumulus, streaked out into a cirrus; on the right hand three long digitate, somewhat convergent striæ, like a bird's wing, and underlaid by a flaky tumor. This flaky substance, very much like a flying pile of down, was not distinguishable from terrestrial clouds, illuminated a pinkish rose color."

In regard to the phenomena known as *Baily's beads*, Dr. Hilgard says:

"The rim of the moon was so *rugged* that the last crescent of the sun was visibly *indented* before being entirely *cut in two* in the lower quarter by a 'mountain of the moon,' while all the rest waved in a very irregular, jagged manner, and very much like a thin rim of ice along the border of a wash-bowl when thawing. The appearance of the last fragments was entirely too *irregular* to leave any impression as of 'beads' at all, but more like irregular telegraphic dots and dashes, and all entirely in accordance with the visible configuration of the moon's edge; while that of the sun itself appeared mathematically exact like a liquid ocean of fire.

"It might be of interest to state that the rugged projections of the moon's rim, during the whole eclipse, appeared as if flickering, mostly from the upper sides like sidewise deflections of light, so that the lower outline (south) appeared firm and distinct; the upper constantly flickered over as in the case of heated air over a field in summer. It may have been that those borders were not then exactly in the achromatic center of the fields, or it may have been, in any case, the flickering of the atmosphere, as I have seen it occur in star-transits at noon; but I cannot exactly account for the difference of appearance on the upper and lower sides, except by imperfect achromacy, a light-colored undulation washing over the upper border, and adark-colored or weak one the lower, leaving the black craggy outlines distinct there.

REPORTS OF OBSERVERS ATTACHED TO THE DES MOINES PARTY.

Report of E. Goodfellow, Esq., Assistant, United States Coast Survey.

AUGUST 21, 1871.

DEAR SIR: As a member of your party at Des Moines, Iowa, I have the honor to submit the following report of my observations there of the total solar eclipse, August 7:

The station selected in the court-house square was about 215 feet north and 47 feet east of the point southeast of the court-house, previously determined in geographical position, and marked by a copper bolt in a stone 14 by 18 inches square. Latitude of this point, 41° 35′ 2″.69; longitude west from Washington, $1^h\ 6^m\ 17^s.49$; and, consequently, position of the eclipse-station, latitude 41° 35′ 04.81, and longitude $6^h\ 14^m\ 29^s.04$ west of Greenwich.

My instrument was a Fraunhofer reconnoitering-telescope (direct vision), focal length 30 inches, aperture 2¾ inches, magnifying-power about 40, showing the entire disk of the sun in the field of view; shade-glass a dark orange color.

Your instructions directed my attention specially to the times of the four contacts, the forms and positions of the protuberances, and the general appearance of the corona. With regard to the protuberances, I was to observe more particularly those which might appear in the quadrant 90° to the left of the vertex.

Sidereal chronometer Kessels 1287 was used to note time. Its corrections and rates were obtained by exchange of telegraphic signals with Springfield, using the known difference of longitude $15^m\ 55^s.42$ between the eclipse-stations.

The following table gives the observed times of the four contacts:

Observed times of the four contacts.

	Chronometer time, sidereal, Kessels 1287.	Mean time observed.
	h. m. s.	h. m. s.
First contact	12 49 2	3 43 06.3
Totality, 1	13 51 30	4 45 23.9
Totality, 2	13 54 30	4 48 23.4
Last contact	14 51 29	5 45 12.8

Occultations of the solar spots, lettered as in the annexed diagram, were observed as follows:

Spot.	Notes.	Chronometer time, sidereal, Kessels 1287.	Remarks.
		h. m. s.	
A	Extreme of faculæ outlying B	13 13 8	
B	First contact	14 45.5	Edge of moon flattened at place of contact.
	Last contact	15 5.5	
C		31 29.5	
D		32 57	
F		34 3	
H	First contact	49 22	

(See Fig. 4, Plate No. 26.)

The first contact with spot H near the edge of the sun's disk occurring not far from totality, the time of last contact was not noted. In my telescope the coming on of totality was marked by a gradual diminution of the thin crescent of light on the northeastern edge of the sun, and then its sudden extinction; no traces of beads or interruptions in the line of light being noticed. Having noted the time of total obscuration, and taken off the screen-glass, I sketched the outline and position of the three brilliant rose-colored protuberances on the southeastern edge of the sun, as shown in Fig. 5, Plate No. 26. This was about six or seven seconds after totality. These protuberances were so striking in appearance that they arrested my attention entirely, and I did not see the smaller elevations which appeared (most probably at a later time) on the northeastern quadrant.

After a hasty glance at the corona, catching sight at the same time of Mercury and Venus, I looked again into the telescope, and saw, about a minute before the end of totality, the peculiarly-shaped, comet-like protuberances on the southwestern quadrant, but had no time to sketch accurately their shape or position, fearing lest I should lose the instant of the sun's re-appearance. This was noted, perhaps, a second late, as I waited an instant after a point of light sparkled on the moon's edge to make sure that it was not another of the rose-colored flames.

The diminution of light began to be quite marked about fifteen minutes before totality, and, as the dark shadow fell, the lantern, previously lighted, flashed on the face of the chronometer a sudden illumination, without the aid of which it would have been almost impossible to note the time.

A slight haziness in the atmosphere, which had prevailed all the afternoon, detracted but little from the beauty of the corona. With the naked eye, the protuberances appeared to me as diamond-like points of light on the edge of the moon's disk, but I could not have made out their vivid rose-colored tint without the telescope.

The general effect on the landscape I was not in a position to observe, and my sketch of the corona was too hastily made to be worthy of preservation; but, limited as was the extent of my view, the impression of beauty and sublimity produced by the total eclipse was one to endure for a life-time.

Very respectfully, yours,

EDWARD GOODFELLOW.

J. E. HILGARD, Esq., &c.

Report of J. H. Lane, Esq.

WASHINGTON, D. C., *August* 28, 1869.

DEAR SIR: By your direction, I proceeded on Tuesday, the 3d of August, to Des Moines, in Iowa, for the purpose of aiding in the observation of the eclipse of the sun on Saturday, the 7th. I arrived in Des Moines in the middle of the night of Thursday, and reported for duty the next day. Before we left Washington, it was expected that I would use a Coast Survey reconnoitering-telescope of 3 inches aperture and 46 to 47 inches focal length. I was directed to observe times of the first and fourth contacts of the moon's limb with that of the sun, and to look after the phenomena of totality. The times of second and third contacts of the limbs were left to my own discretion, not to be noted unless it could be done consistently with the points to which I wished to direct my attention at totality, which also were left in great measure to my own discretion. After our arrival in Des Moines, a change was made in the assignment of the instrument with which I was to observe. Professor Newcomb, of the United States Naval Observatory, had taken out with him, and fitted temporarily with a wooden tube and wooden mountings, the object-glass of the refraction-circle of the observatory. That of the transit-circle of the observatory was also fitted up in the same manner; and as the former of these two large glasses had not been otherwise appropriated, it was, at the instance of Professor Newcomb, arranged between you and him that it should be assigned to me. I gladly accepted the use of so powerful an instrument, though not without misgivings that it might have been more useful in the hands of a more experienced and expert observer.

This glass had a clear aperture of 5.9 inches, and, according to a measurement roughly made since my return to Washington, a focal length of about 8 feet 7 inches. The eye-piece exclusively used with it was a positive or Ramsden eye-piece, in the field of view of which 0.26 inch is found to subtend to the eye an angle of about 13° 36′, which corresponds to a virtual or compound focal length of 1.1 inches. The magnifying-power of the instrument was therefore not far from 94. The full aperture was, then, large for the power, and showed the details of the solar spots and faculæ beautifully well defined during the period of the eclipse. Some apprehension, however, having been expressed of undue heating of the eye-glasses by the sun's rays, the aperture was contracted, during the early part of the progress of the eclipse, by means of a screen, in the center of which was cut a circular opening, of a diameter which I judge to have been a little over two inches. The inferiority of definition by this contracted aperture, as compared with that of the full aperture, was very marked indeed, and yet it gave a completely satisfactory observation of the first contact. Before the eclipse was over, it became evident that the full aperture might have been used from the first, without injury to the eye-glasses, and the last contact was observed with the full aperture of 5.9 inches. It is the eye-lens above, that is exposed to the greatest intensity of radiation, together, of course, with the colored screen-glass usually placed immediately in front of it. In place, however, of the screen-glass so used, I introduced a deeply-colored glass into the field of view itself, that is, into the focus of the object-glsss. The primary object I had in view in this will be stated in the report I am directed to make to the head of the United States Naval Observatory. But besides the particular purpose which led me to use the colored glass in the field of view, such a disposition of it, supposing it to be of a material that largely absorbs the heat-rays as well as the luminous, carries with it an important advantage in regard to the heating. In the instrument employed in this case, the image of the sun was almost an inch in diameter, and the heat-rays consequently were even less *concentrated* than at the focus of a much smaller glass of the usual proportion of focal length. The advantage of so extended a surface for the absorption and dissipation of the heat-rays is obvious. The colored glass I used was a deep-blue glass, one-eighth of an inch thick, as near as I could guess, loaned me by Dr. Hilgard, of Saint Louis, who was of our party. It showed the sun's disk soft and easy to the eye, and the heating at the eye-lens was so slight that it was not noticed even with the full aperture. What is to hinder the fitting of screen-glasses in this manner as a general rule? It might be expedient to separate the glass far enough from the focus to prevent slight scratches from showing, and it would always be necessary to remember that the introduction of the plate into the *conical* part of the pencil, whether at the focus or elsewhere, displaces the focus through an interval equal to one-third the thickness of the plate (for a glass of index $1\frac{1}{2}$), but would there be any material inconvenience in this?

Originally I intended to observe the contacts with the colored screen-glass that accompanies the eye-piece; but, as the time of first contact approached, it was found impossible to bring it to bear, because the cap in which the eye-hole is made could not be unscrewed from its place. Accordingly, the first contact was from necessity observed through the blue glass, slid into the field of view for that purpose; but it proved so satisfactory, notwithstanding some scratches which it showed in the field, that it was used for the fourth contact from choice. I have already stated that the first contact was taken with a reduced aperture, judged to be a little over two inches in diameter, and that this showed the contact very satisfactorily. The eye seemed to detect the first touch of the moon's limb to that of the sun, and it was some four seconds before I ceased watching for *complete assurance* of the *indentation*. It is not easy to say what gives the eye its first impression of the change. It has been suggested that it may depend more on a certain change in the character of the boundary than on any perceived indentation, and this suggestion offered itself independently to myself. If it be a change in the character of the boundary, the change seems too subtle to be easily traced. I am not sure that on this occasion, and on the occasion of the eclipse of May 26, 1854, when, with an excellent reconnoitering-telescope of the Coast Survey, I observed the phenomena, though not the times, of both contacts with all the care and scrutiny I could command, the instant of first contact has not been better appreciated than that of last contact, as if the supposed peculiar condition due to the touch of the moon's limb produces upon the eye a more marked effect by its advent than by its departure.

I here give the times of first and last contacts as noted by me by chronometer Negus No. 1281, without applying the correction for the error of the chronometer:

NEGUS No. 1281.

First contact	$9^h\ 56^m\ 08^s$
Fourth contact	$11^h\ 58^m\ 26^s$

As I have been instructed to make my report upon the totality to the head of the observatory, I am, of course, not expected to say much of that part of the observation here. You were asking me if I saw Baily's beads. In answer, I will anticipate the subject of my report to the observatory so far as to say that the uncovered part of the sun's disk was viewed through the blue glass in the field of view, and that as soon as the light of the sky near the crescent became tolerable to the eye, the blue glass was slid partly out of the field, so as to leave free passage for the light from the field of view to the eye, except that part of the field in which the crescent was viewed through the blue glass. It must be recollected that my attention was given primarily to that part of the moon's limb near to the crescent, but beyond the cusp and beyond the edge of the blue glass. Yet the northern cusp and the middle of the crescent were in view, and an impression was left on my mind that the last portions of the crescent fell off in fragments. A similar observation has been before reported by some one else in a former eclipse. So far as I can rely on my own impression in this case, it cannot be better described than by saying that it was not calculated to excite surprise after the prominent manner in which the irregularities of the moon's outline had been seen projected on the soft blue of the sun's disk. I must not omit to state here that after the beginning of the eclipse, and before the approach of totality, the colored glass (a red glass, I believe) was brought to bear in the common way before the eye-lens, and that the telescope was focused upon the solar spots by its use, with the blue glass slid from the field of view, so that afterward the open part of the field of view, in which the corona was to be watched at the near approach of totality, might be in good focus in preference to the part to be then occupied by the blue glass; but that upon removing the red glass, and sliding the blue glass back into the field of view, it was found that the eye readily accommodated itself to the change of focus so produced.

I will take this occasion to add a little account of the observations, already alluded to, which I made upon the solar eclipse of May 26, 1854. The observations were entirely negative as to result, yet, as was remarked to me by a scientific friend at the time, such observations may be worth reporting when they have any bearing upon actually mooted points. The Coast Survey telescope loaned me on that occasion had, as near as I can remember, a clear aperture of, say, $2\frac{1}{2}$ inches or upward. My object was to watch for some of the mysterious phenomena which have appeared to present themselves to other observers at the contacts of the moon's limb and during

the progress of the eclipse. I prepared for the occasion by fitting up a dark room at a west window of the east wing of the Patent-Office, mounting the telescope in the window. The sun's image was thrown upon a screen at a short distance from the eye-end of the telescope, giving the image a diameter somewhat in the neighborhood of two inches, as near as I can remember, or such as seemed most satisfactory to the eye by showing the definition with suitable intensity of illumination. The first contact was observed in this manner. What I particularly looked for was a peculiar phenomenon which had been reported by some observers at the time of contact of the limbs. I believe it was the formation of a notch in the sun's disk at the point of contact. At any rate, nothing marvelous appeared. The eye was, perhaps, impressed by a difference in the character of the boundary formed by the moon's limb, but the form of the boundary, from the very first instant of contact onward, was nothing else than the form of that part of the moon's limb as seen when fully advanced upon the sun's disk, so far as I could see. The sky was beautifully clear during the entire period of the eclipse, and the contact was well seen. A short time after the beginning of the eclipse I preferred to discontinue the use of the screen and view the sun directly with a colored glass. I made it my chief business during the continuance of the eclipse to look for the fringe of light which has sometimes been reported as seen along the moon's limb projected on the sun's disk. I saw nothing of the kind except what was distinctly traced at the time to the eye itself. I experimented on this point all through the time of the eclipse. Whenever the eye was held for some little length of time without a wink, and in complete fixity upon the object, all distinctively border-light invariably disappeared, leaving nothing but purely the projection of the moon's form upon the sun. But not the slightest movement or change in the eye could take place, with this point on the attention, without calling into instant being a colored border, often very vivid. The cause of this is too obvious and well known to be pointed out here, and it is only the negative part of the observation that there is any occasion to mention.

The wavy motion along the moon's border, which had also been mentioned by some observers in connection with eclipses, was another object of attention on that occasion. Such wavy motion as I saw did not appear distinguishable from that which is generally seen in telescopic observations.

Finally, at last contact nothing was seen more than at first contact. The last contact was observed with a screen-glass. I do not undertake to give the color of the glass used in any of these observations, as I cannot do it with certainty. The presumption is that it was a red glass.

Respectfully submitted.

J. HOMER LANE.

Professor HILGARD, &c.

Report of Mr. S. A. Cecil.

The telescope used had 3-inch aperture and 47-inch focal length, and belonged to the United States Coast Survey. Chronometer, Kessels 1287. Times entered require the correction of the chronometer to be taken into account.

First contact imperfectly observed.

	h.	m.	s.
Contact with spot marked A at............	13	13	12
Contact with penumbra of B at............		14	06
Contact with spot marked B at............		15	03
Contact with spot marked C at............		31	30
Contact with spot marked D at............		33	04
Contact with spot marked E at............		34	01½
Contact with spot marked F at............		36	24½
Totality commenced........................	13	51	33
End of totality not accurately observed.			
Last contact at............................	14	51	35

(See Fig. 6, Plate No. 26.)

But little reliance should be placed on any of the times put down, unless corroborated by other observers; observer being quite unused to observations of precision, and therefore keeping time imperfectly. The first minute of the totality was lost in adjusting the telescope (which, on account of the small field, required constant alteration to proper portion of sun's disk allotted to

observer). Almost the whole remaining time was occupied in observing the large prominence roughly sketched. It was of a decided pinky red color, standing out with, as it were, a background of brilliant white light, presumed by observer to be the "corona." The appearance was as of space between the prominence and its background, the former being exceedingly sharply defined. Through the telescope the prominence appeared brighter in proportion to its color than its background. The other prominences on the left-hand quarter were only glanced at through the telescope. The portion of the sun's disk in view was too small to obtain more than the one prominence in view at a time. A hasty glance seemed to show that this was the only one that came in observer's quarter of disk (afterward proved incorrect), and he therefore confined himself solely to observation of this one. His observations with the naked eye were very imperfect. Through the telescope the prominence appeared like incandescent gas of a semi-transparent ruby look about it, and reminded one of steady flame rising up from a large fire clear of smoke and blown violently over in one direction by a gust of wind, which seemed to have more effect on the top of the prominence than on its base. No detached portions were observed, as stated by some to have been seen in another part of the sun's disk. Comparatively slow changes of form appeared to be going on in the prominence.

Magnetic observations at Des Moines.

Observations of the three elements were made on August 8, near the astronomical station, in the court-house square, yielding the following results:

Declination.......... ..	9° 56′ east.
Dip....................	71° 13′.
Horizontal intensity....	4.313.

Observations to determine the northern limit of totality.

Dr. Asa Horr, of Dubuque, Iowa, kindly undertook to make arrangements for observations to determine the northern limit of totality, in the vicinity of the town of Cedar Falls. It was supposed that the limit would pass some distance to the south of the town, and the disposition of observers was made accordingly; but the event proved that the limit was several miles to the westward of the places of observation.

Through Dr. Horr's endeavors a number of stations were laid out by a competent surveyor, under the direction of Mr. W. I. Anderson, civil engineer, of Dubuque, at intervals of half a mile, one of them being the cupola of the Soldiers' Orphans' Home. These stations are shown on the plan (Fig. 7, Plate No. 26), as well as the place of observation in the town of Cedar Falls, and the astronomical station, from which the geographical positions are derived.

Trustworthy observations of the duration of totality were obtained as follows:

At station No. 5, by Mr. W. I. Anderson, 71 seconds.

At station No. 2, by Mr. E. W. Horr, 63¾ seconds.

At station No. 0, by Mr. J. H. Stanley, 51 seconds.

In addition to these values, Mr. E. W. Horr observed the following:

	h.	m.	s.	
First contact	3	52	37.50,	Dubuque time.
Beginning of total phase........	4	57	00.25	
End of totality..................	4	58	04.00	
Last contact.....	5	53	10.00	

His watch, however, was not thoroughly rated.

The preceding observations were made with stop-watches, having independent second-hands marking quarter-seconds. They were set to 60, started when the totality commenced, and arrested when the light re-appeared.

The report of Messrs. Anderson, Horr, and Wormood, to Dr. Asa Horr, president of the Iowa Institute of Science and Art, is appended below.

The position of this station is 3,089 yards south and 1,172 yards west of the astronomical station in Cedar Falls, which was subsequently ascertained to be in latitude 42° 32′ 32″.3 ±

0″.45, and longitude $19^m\ 20^s.54$ west of Dearborn Observatory, Chicago. These determinations were made in October by Sub-Assistant F. Blake, junior. The latitude was determined by observations on twelve pairs of stars, on a single night, with a 26-inch zenith-telescope (No. 6); the longitude by telegraphic exchanges of time-signals on two nights with Chicago, the observations at the latter place being made with the transit-circle by Professor T. H. Safford, who kindly co-operated in the determination, while those at Cedar Falls were made with a 26-inch transit (No. 7).

The several results are:

Cedar Falls, west of Chicago, October 25, $19^m\ 20^s.63$
October 26, $19^m\ 20^s.46$

It is upon these results that the meridians and parallels on the sketch (No. 7, Plate 26) are based.

The following observations of the eclipse in Dubuque were made by Dr. A. Horr, at his observatory, in latitude 42° 29′ 38″, longitude 13° 37′ 02″.7 west of Washington:

First contact, $3^h\ 55^m\ 45^s$
Last contact, $5^h\ 55^m\ 39^s$

"The chronometer was carefully corrected by transit-observations on stars. Thermometer fell during the eclipse from 72° to 64°, and dew deposited slightly on the grass."

Dr. Horr took great pains to obtain observations made by persons living near the limit of totality, and has communicated the following:

"*August* 17, 1869.—Yesterday I was in the vicinity of the northern line of the umbra of the recent eclipse, and obtained the following facts from Mr. H. S. Hoover, of Waverly, who is a very intelligent surveyor:

"The family living within a few rods of the northeast corner of the southwest quarter of section 18, township 92, range 16 west, saw the eclipse total for an instant. Another living at the northwest corner of section 17, same township, saw the margin of the sun during the period of greatest obscuration. This, as you will see, would fix the line within two-thirds of a mile, which passes five miles west of Clarksville, Butler County. I requested Mr. Hoover to search for similar facts, and to send me the results."

The position indicated is marked on the map of a portion of Iowa, given on Plate No. 26, as are those reported below.

From Marion, Linn County, Iowa, Mr. J. W. McClellan, principal of the public schools, makes the following communication to Dr. Horr, under date of September 7, 1869:

"After making search in different directions over this and adjoining counties, in a northwesterly and easterly direction, we found the line of *totality* in the following places, viz: In section 16, township 85, range 6 west, 5 north, P. M., we found the line of totality to extend from the northwest corner of the within-named township toward the *southeast* corner of the same.

"In the *northeastern* part of Linn County we found the line of totality to extend in the *same* direction across section 23, township 84, range 5 west, 5 north, P. M.

"I have consulted Captain Gray, county-surveyor, and I find the within-named localities correct."

Dr. Ristine, of Marion, in transmitting the preceding letter, remarks:

"In the diagram (No. 9, Plate 26) you will observe the shadow passed between the two houses 1 and 2, which are situated just half a mile apart, on a direct east and west line. The family at No. 1 state that it was total, but that the duration of totality was so short that they were unable to estimate the time. Mr. Clark, at No. 2, informs me that the sun was clearly visible. Others in the same locality corroborate the statements in the matter."

In addition to the foregoing, Dr. Horr communicates the following letter from Mr. H. S. Hoover, of Waverly, dated September 28, 1870:

"Last fall, in September, I looked along the north margin of the eclipse one day and a half, and but few could give me any satisfactory answers, but have been expecting time after time to make further investigations, and therefore laid my minutes aside and forgot them until to-day. I picked them up among my papers, and will give the sum of my observations that the northern limit was on the line of the northwest corner of section 19, township 19, range 13.

"The following are minutes of the information, in part, upon which this conclusion is based:

"J. W. McKinney, living thirty rods north of the east quarter-post of section 31, 90, 13, says the

eclipse was total only a few pulsations. The sun appeared with only a small ring, as the new moon appears at times.

"John Christie was on the west half of the southeast quarter of section 19, 90, 13, at work, and says the disk of the sun was entirely covered. He did not take his eyes from the sun from the time the sun was nearly covered until the rays appeared again.

"Mrs. Susan Simons says she was at the front door of her house, southwest corner of the northeast quarter of section 30, 90, 13, with a telescope, and several of the family with her, and the eclipse was total, no rays appearing on either side of the sun for a few seconds. Conversed intelligently about the matter.

"Mrs. Tennison, living forty-five rods north of southwest corner of northwest quarter of section 24, 90, 14, says that she watched the eclipse carefully and found it covered a few pulsations only.

"I found none of the residents north of the southwest corner of the northwest quarter of section 12, 90, 14, that pretended to claim that the eclipse was total above that line.

"I am sorry that the matter was so long delayed."

The following is the report of the observers at Cedar Falls:

"DUBUQUE, *August* 9, 1869.

"*To the President of the Iowa Institute of Science and Art:*

"DEAR SIR: In compliance with your request, we visited Cedar Falls, Iowa, on the 7th instant, to make observations upon the duration of the total phase of the eclipse of the sun. We were provided with five first-class double and single quarter-second watches, which were generously furnished for the purpose by Giles, Morse & Co., of this place. We were kindly assisted by George C. Dean, of Dubuque, and by J. H. Stanley and J. J. Tolerton, of Cedar Falls, who took stations as observers. The line of observation and the positions of the observers were located by E. Rodenberger, civil engineer, who also furnished an accurate plat of the same, which is herewith presented. At 12 o'clock noon, we corrected the watches by the signals transmitted by telegraph of the precise mean time of Dubuque. The first station was half a mile northeast of the Soldiers' Orphans' Home, which is two miles south of the city; the second at the cupola of the Orphans' Home; the third, fourth, and fifth on the same line, half a mile apart, extending southwest.

"In due time the stations were occupied, the first by George C. Dean, second by E. W. Horr, third by W. W. Wormood, fourth by J. J. Tolerton, and the fifth by William I. Anderson. In addition, an observation was made by J. H. Stanley opposite his store, on Main street, each of whom were provided with colored glasses, lanterns, and assistants.

"The sky, which had been clear during the day, became slightly hazy a short time before the beginning of the eclipse, but which did not, in any respect, interfere with the perfection of the observations. The wind blew a gentle breeze from the east.

"At the store of Wise & Bryant the average temperature in the shade, before the eclipse, was 74°, which, at the period of totality, fell to 67°.

"At the Orphans' Home, the first contact was at 3 o'clock 53 minutes and 42 seconds; duration, 2 hours 32½ seconds.

"Total phase lasted 63¾ seconds, with a variation from 71 seconds at one and a half miles southeast of the Orphans' Home to 51 seconds in the city. Corona was well defined. The moments of immersion and emersion of the sun were startlingly instantaneous, and were of such thrilling interest to behold as to require no ordinary power of attention to secure accuracy in recording the period of duration. During the time, dew deposited plentifully on the grass.

"At the southwest, the darkness was of the blackest character, while at the northeast, through a lurid haze, trees could be seen basking in the dim sun-light in the vicinity of Janesville, eight or ten miles distant.

"This was the most wonderful natural phenomenon ever witnessed by the citizens of Cedar Falls, and of more interest than any that will be observed there in the present century.

"Acknowledgments are due to Superintendent Farley for passes over the railroad, and to the telegraph-agents for the free use of the lines.

"Very respectfully,

"ED. W. HORR.
"WM. I. ANDERSON.
"W. W. WORMOOD."

Observations near Saint Louis to determine the southern limit of totality.

Arrangements for observing the southern limit of totality were kindly undertaken by Major J. Pitzman, county-surveyor for Saint Louis, who, aided by Messrs. Eimbeck, McMath, Soldan, Cobb, McKown, Burgas, and Schmidt, occupied five positions arranged across the path of the shadow at distances of nearly one mile apart, and observed the duration of the eclipse. The stations are shown on diagram No. 10, Plate 26. The following reports of Major Pitzman and Professor Eimbeck give all the essential facts, to which it is only necessary to add that none of the observers had ever witnessed a total eclipse of the sun, and that Messrs. Pitzman, Eimbeck, and McMath are accustomed to observations of precision.

It will be seen that the absolute times are not to be depended upon for want of more precise determinations of the chronometer-corrections, but that the intervals between the observations are doubtless well measured by the time-pieces.

Major J. Pitzman's report.—Observations made August 7, 1869, *at points on the track of the Terre Haute Railroad between Saint Louis, Missouri, and Alton, Illinois.*

Took first station at Coal Switch, a point about three miles southeast of the confluence of the Missouri and Mississippi Rivers.

		h. m. s.	
Station 1.—Burgas and Schmidt	Beginning	4 3 58½	
	Totality	5 4 23¼	Duration, 66¼ˢ.
		5 5 29½	
	End	6 1 9½	
Station 2.—Cobb and McKown	Beginning	4 4 15	
	Totality	5 4 34	Duration, 64ˢ.
		5 5 38	
	End	6 0 22	
Station 3.—Pitzman and Soldan	Beginning	4 4 —	
	Totality	5 4 46	Duration, 46ˢ.
		5 5 32	
	End	6 1 24	
Station 4.—William Eimbeck	Beginning	4 2 58	
	Totality	5 4 57	Duration, 32ˢ.
		5 5 29	
	End	6 1 47	
Station 5.—Robert McMath	Totality	5 4 59	Duration, 10½ˢ.
		5 5 09½	

The stations have been taken about one mile apart, and the distances obtained by pacing. The observations at station 2 have not been taken with the necessary accuracy, and the end of totality is noted too late; at stations 1, 2, and 5, the observations have been made with colored glasses; at station 3 with a large binocular glass furnished by the Coast Survey; and at station 4 with a three-foot telescope, and the time measured with a chronometer. All watches had been carefully compared one and a half hours previous and after the eclipse, and the differences divided in proportion.

All of which is respectfully submitted.

JULIUS PITZMAN,
County-Surveyor of Saint Louis County, Missouri.

Report by Professor William Eimbeck to Julius Pitzman, Esq.

SIR: I submit to you the results of my observations of the solar eclipse, August 7, 1869, at a point near the southern limit of the shadow and within it.

Station occupied some 10 feet west of seven-mile post, between Coal Switch and Mitchel Stations, Saint Louis and Alton Railroad, and about three miles southwardly of the former. At 4 o'clock p. m. fixed my refractor (of 34 inches focal length and 2.4 inches clear aperture) upon the point in the sun's northwestern edge I had previously calculated as the point of first contact (see diagram No. 11, Plate 26). At $4^h\ 2^m\ 28^s$, as indicated by the Hodell chronometer, this first contact occurred at the very point where I had been watching it, and thus recorded it, perhaps, within a second or two correct.

The diagram represents the solar disk with its clusters of spots as shown by my instrument. Their relative positions have been sketched with care. The position of the meridian and the other lines in respect to the "vertical" correspond to the instant, $4^h\ 4^m$, or the assumed time of the beginning of the eclipse. (Hour-angle assumed 59° 30′.) The moon's edge in its passage over the sun's disk touched the little distinct spot designated No. 1, *a*, at $4^h\ 28^m\ 10^s$; No. 2, *c*, at $4^h\ 47^m\ 11^s$ (*b* and *c* could not be observed; a patch of drifting feather-cloud obscured distinct vision). Of the cluster of spots designated, No. 3, *c*, was touched by the moon's edge at the instant $4^h\ 44^m\ 52^s$. The nstant of total obscurity occurred at $5^h\ 4^m\ 57^s$. Baily's beads beautifully distinct and apparently spreading over an arc of more than thirty degrees. Noticed them all round as the "horns" of the new moon—"in the arms of the old"—shortened. Immediately after the last sunbeam had vanished, I removed the "London smoke," for which I had previously prepared, and which I had attached to the eye-hole of the refractor with a little wax; but finding it difficult to get the luminaries into the field of the instrument again, and not knowing of what duration the total obscurity might be, I observed the re-appearance of light without its aid. This ensued at the instant $5^h\ 5^m\ 29^s$. Both these instants, however, may have been recorded a second or two later than what, perhaps, should be considered the true instants of beginning and end of totality, because, in the first instant, the light of the "beads," several in number, faded away so gradually as though it never would totally disappear, and the instant recorded corresponds to the disappearance of the very last bead. The second instant or re-appearance of light, because it was observed through the "London smoke" with the naked eye. The duration of totality, therefore, cannot be materially erroneous, provided, of course, the time was noted correctly, which in both these instances I could not verify. The last contact of the edges of the two luminaries admitted of very exact observation and occurred at $6^h\ 1^m\ 47^s$.

The time was recorded by W. H. Rodgers, an experienced clock-maker, and has been checked by myself, except in the two instants marking the totality as above mentioned. The extreme anxiety to observe with the utmost accuracy the proper moments of beginning and end of totality, as well as the exciting display of this most wonderful and sublime phenomenon that ever my eyes witnessed, made me forget this duty.

The (Hodell) chronometer was adjusted to Saint Louis mean time. A comparison with the (Dent) chronometer belonging to Professor Chauvenet, at 10 o'clock a. m., August 7, 1869, and several days previous, was made in order to determine and check the effect of transportation by railroad, &c., upon its rate. Professor Chauvenet's chronometer, by certificate of himself, indicated correct Saint Louis local time June 23, 1869, and has a plus rate of 1.8 seconds per day.

	m. s.
Dent ahead of Hodell (before departure) August 7, 1869, 10^h a. m.	1 21
Dent ahead of Hodell (after return) August 8, 1869, 10^h a. m.	1 25
By comparison, August 9, 1869, 10^h a. m.	1 27

From this it would follow that the effect produced upon Hodell by transportation, &c., equals a loss of $2\frac{1}{2}$ seconds in time nearly. Assuming $1\frac{1}{2}$ seconds to be an approximate value for this correction, and recapitulating, we have—

	h. m. s.
First contact of edges, at	4 2 $59\frac{1}{2}$
Last contact of edges, at	6 1 $48\frac{1}{2}$
Duration of eclipse generally	1 58 49

	h.	m.	s.
Instant of total obscurity	5	4	58½
End of totality on re-appearance of light	5	5	30½
Duration of totality			32

My object in making the foregoing report so elaborate was solely to enable you to bring the several observations into a proper bearing to each other and to limit the "weight" due to each.

Respectfully yours, &c.,

WM. EIMBECK,
Civil Engineer.

The observations obtained indicating that the limit of totality could be inferred from them with considerable precision, it became desirable to ascertain the geographical positions of the stations with some degree of exactness. It was judged advisable to make the requisite observations of latitude and longitude at some point within the city, and refer the eclipse-stations to the same by triangulation, both on account of the convenience of observers and because the geographical position of Saint Louis had never before been ascertained with precision. Arrangements were therefore made with the officers of Washington University, in pursuance of which piers for the instruments of the Coast Survey were erected by them on the grounds of the university, and a temporary building was put up over them at the expense of the Coast Survey.

The observations for latitude were made in December, 1869, by Mr. O. H. Tittman, of Saint Louis, aid in the Coast Survey, with a 23-inch zenith-telescope, by twenty-six observations upon nine pairs of stars. The resulting latitude is 38° 38′ 03″.2, with a probable error of ± 0″.2.

Additional observations were subsequently made by Professor Eimbeck with the same instruments, yielding 38° 38′ 03″.30 ± 0″.16 from forty-three observations upon twenty-eight pairs of stars.

The observations for longitude were deferred until the following April, on account of the unfavorable season. They were made by Professor William Eimbeck, of Saint Louis, in conjunction with the United States Observatory at Washington. At Saint Louis the instruments used were a 26-inch transit and sidereal chronometer, the correction of which was determined by the observation of not less than seventeen stars on each night. After star-observations, the chronometer was compared by coincidences of beat with another chronometer going to mean time, which was then carried to the telegraph-office, whence signals coincident with its beats were sent to Washington and recorded upon the chronograph at the United States Observatory, on which the beats of the sidereal clock were at the same time registered. Next the Washington clock was put into the circuit, and its beats, repeated at Saint Louis, noted by coincidences with those of the mean-time chronometer, which was finally carried back to the Observatory, and again compared with the sidereal chronometer, in order to make certain that no derangement had taken place during transportation.

The observations at Washington were made by Professor William Harkness, United States Navy, with the twelve-foot telescope of the transit-circle.

The following are the results of four different nights on which observations were obtained at both places, and signals successfully exchanged:

Saint Louis west of Washington.

	m.	s.
April 12,	52	36.92
23,		36.89
26,		36.95
30,		36.97
Mean,	52	36.93

The greatest difference from the mean is $0^s.04$, or one twenty-fifth part of a second.

The difference in time or longitude between the two places derived from the signals sent *eastward* will appear too *small* by the length of time required for the transmission of signals along the

telegraph-wire and through the repeating and recording instruments, and too *large* by the same amount from the signals sent *westward*. The effect disappears in the mean of the two comparisons, and half their difference measures the time of transmission, which in the present case was $0^s.16$, or about one-seventh of a second of time.

In order to ascertain the personal equation between the two observers, Professor Eimbeck subsequently proceeded to Washington and observed the time, at a point in the meridian of the transit-circle, with the transit and chronometer used at Saint Louis, and compared his time so obtained with that observed by Professor Harkness with the transit-circle and chronograph, in the same manner in which the comparisons had previously been made when observing at Saint Louis. It was thus ascertained that Eimbeck was on the average later than Harkness by $0^s.08$, by which amount the longitude above given must be diminished. At the same time, the transit-circle being $0^s.07$ west of the center of the observatory to which the longitudes are referred, we must add that quantity and obtain finally, for the longitude of the station in Saint Louis, west of Washington, $52^m\ 36^s.92$, which value is not uncertain more than two-hundredths of a second. The Washington Observatory dome being $5^h\ 8^m\ 12^s.06$ west of Greenwich, we obtain for the station in Saint Louis $6^h\ 00^m\ 48^s.98$.

In order to reduce the observed values to the center of the court-house, we must deduct from the latitude $25''.7$ of arc, and from the longitude $3^s.63$ of time, so that we have finally, for the court-house of Saint Louis, latitude, $38^\circ\ 37'\ 37''.5$; longitude, $6^h\ 0^m\ 45^s.35$; or, in arc, $90^\circ\ 11'\ 20''.25$.

The public are indebted to the Western Union Telegraph Company for the free use of their lines, kindly granted through General Anson Stager, superintendent of the western division, for the purpose of the foregoing determinations. Special acknowledgment is due to Mr. M. D. Crane, of the Western Union Telegraph Office in Saint Louis, for his assistance in the transmission of signals and messages, which was rendered gratuitously, as was all the arduous and long-continued work of Professor Eimbeck.

J. E. HILGARD,
Assistant, United States Coast Survey.

WASHINGTON, *October* 10, 1870.

Observations of the eclipse at Cherokee, Iowa.

OMAHA, *August* 24, 1869.

DEAR SIR: I observed the late total eclipse at Cherokee, Cherokee County, Iowa, about sixty miles inland from Sioux City, quite successfully, as far as my means and instruments permitted. I had a clock; Morse register for chronograph; portable transit, 32-inch; and an ordinary telescope, pillar and claw mounting, of 4 feet focal length and 3.3 inches aperture. I had also a railway-transit, with additional lens over object-glass, by which I could directly read the position of the end of the needle for variation, somewhat after the manner of variation-transit; also barometer and thermometer. The observed contacts in local sidereal time are as follows, subject to some correction on final determination of error and rate of clock from observations for time:

	h.	m.	s.
Beginning of eclipse	0	37	42.5
Beginning of totality	1	44	06.3
End of totality	1	44	06.7
End of eclipse	2	42	03.9

The approximate latitude of place of observation is $42^\circ\ 46'\ 26''$, and the assumed longitude $1^h\ 14^m\ 20^s$ west of Washington. I had no means of properly determining the longitude; the railway from Fort Dodge to Sioux City being not yet completed, and therefore decided to defer the determination of that element a few months, until it can be done by telegraph. The magnetic declination observed was about $11^\circ\ 32'$ east. Careful observations during most of an entire day were made at intervals of one hour.

I shall be pleased to send you a statement of my observations complete when properly reduced, if you would like to have them. The phenomenon was grand, indeed, as you characterize it; the corona and the rose-colored flames were very distinct.

Very respectfully,

J. BLICKENSDERFER, JR.

J. E. HILGARD,
United States Coast Survey, Washington, D. C.

OBSERVATIONS AT KOHKLUX, CHILKAHT RIVER, ALASKA.

SAN FRANCISCO, CALIFORNIA, *September* 9, 1869.

DEAR SIR: The path of totality of the solar eclipse of August 7, through Alaska, passed nearly parallel to the coast-line from the head of Cook's Inlet to the Stakeen River, but, from the information I gathered in 1867, I found it would be impracticable to carry instruments and provisions up the Sutchitna or Kneek Rivers from Cook's Inlet; across the mountains that border Prince William's Sound; up the Atna or Copper River; across the mountains at the head of Behring's Bay; or up the Alsegh River. Natives do cross the Saint Elias range by the latter river to the valley of the Chilkaht River, but only in winter with snow-shoes.

The Yukatat or Saint Elias range, with its hundreds of glaciers, and average elevation of 8,000 or 9,000 feet, effectually bars transportation; moreover, the country on the east flank is uninhabited, and throughout affords no means of sustenance.

In 1867 I examined the mouth of the Chilkaht River, emptying into the head of Chatham Strait, between two high mountain-ranges, in latitude 59° 12′, only forty or fifty miles in a direct line south-southwest from the central path of totality. This, too, was the nearest point to that line reached by navigable waters. It also offered the opportunity of my observing the transits of the limbs of the sun and the moon during the eclipse over the meridian, as I had done at Humboldt Bay in 1864.

In undertaking the conduct of this expedition in 1868, I determined to ascend the Takou River or the Chilkaht. Sir James Douglas, in answer to my inquiries, wrote me that the Chilkaht and Takou were unexplored; that the latter, for forty or fifty miles, passed through a very mountainous region filled with glaciers. This decided me to ascend the Chilkaht, the lower reach of whose valley I had seen for ten or fifteen miles, and having learned from the Indians that they traded as far northward as Fort Selkirk, on the Youkon River.

Our first understanding was, that not only should observations of precision be made, but observations with the spectroscope; and that photographic pictures also should be taken. Your letter of November 18, 1868, however, limited my action so as to "secure the greatest precision in observing the phases, time, &c., with reference to data for the longitude," while spectroscopic observations and photographic impressions were to be undertaken only in case volunteers should offer for such duty. On May 18, you informed me that "no spectroscope was available for my use." No volunteers offered for such a long and hazardous undertaking; no steamers were running to Sitka; and from Sitka I had to trust to canoes for a rough trip of two hundred and fifty miles to my destination.

Lest the whole expense and time of the expedition should be lost by a cloudy day on the 7th of August, I determined to obtain the latitude and longitude of as many positions *en route* as practicable, and to make as many flying sketches of harbors as the time and weather would allow. That work I have already reported to you.

The following are the instruments taken for the whole work:

1. For latitude, time, and azimuth, the new meridian instrument, United States Coast Survey No. 1, of which I have specially reported.

2. For observations of the eclipse, a telescope by Fraunhofer, object-glass, 3 inches diameter; focal length, 45 inches; astronomical eye-piece with power marked 55. In this eye-piece I had a

diaphragm inserted with two threads at right angles, while the inner edge of the diaphragm was cut as a micrometer-rack, with nine teeth to each quadrant. The eye-piece which I had suggested for determination of the position, extent, and elevation of the sun-flames was not made. The instrument was equatorially mounted for a latitude of 45°, and had movement by rack-work in two planes. For some days before the eclipse, the apparent size of the sun in the field of view was well studied, in order to familiarize myself with the approximate determination of angles, and the relative size of objects on the limb. During the eclipse-observation, it was set up in the open air near the transit-tent, and was protected from a light east-southeast air by the fly of a tent.

3. In order to record the times of beginning and ending of the eclipse, beginning and ending of totality, transits of the sun's and the moon's limbs over the meridian, occultation of spots, and other phenomena, the Hipp chronograph, with new helices, was mounted and connected with the Frodsham break-circuit chronometer No. 3479. Both were working very nicely.

4. From San Francisco I had taken seventeen chronometers, of which six belonged to the United States Navy, and had been kindly loaned to me by Lieutenant Commanding E. C. Merriman, of the Mare Island navy-yard. The break-circuit chronometer was only used for this special work. Fearing the dangerous navigation of the Chilkaht River in canoes, I left nine of the chronometers at Sitka, and carried eight to my station on the river.

5. Thermometers and barometers were placed in two positions during the eclipse, but a close systematic series of observations could not be obtained with the limited assistance I had. For the same reason the magnetic instruments were not observed.

6. I had, in addition to the above instruments, octant, theodolite, gradienter, &c., for local surveys.

By the kindness of Major-General Thomas, commanding the Division of the Pacific, I was enabled to reach Sitka on the United States quartermaster's steamer Newbern. Thence there was no vessel available, and I was compelled to undertake the worst part of the journey in an open boat kindly furnished to me by Major-General Davis, commanding the Department of Alaska. A large war-canoe, with a chief and six men of the Sitka tribe, carried part of my provisions and instruments.

My experience upon this coast with Indian tribes was such that I declined any escort of soldiers. My party consisted of Mr. S. R. Throckmorton, jr., as aid, and four men, and no interpreter. The tribe of Chilkahts numbered 1,500, and was considered the most hostile on the coast, especially as General Davis had recently kept their chief ten days in the guard-house, and shot one or two of their men in trying to pass the guard. The officers looked upon my undertaking as reckless. I did not.

The day I left Sitka was the commencement of bad weather, and I was attacked with Panama fever, so that we were eleven days in reaching our station "Kohklux," at the Chilkaht village of Kot-kágh-too, on the left bank of the Chilkaht River, in latitude 59° 23′ 42″, and longitude 135° 58′ 12″. Here the valley of the river is about two miles wide, and the mountains on each side reach an elevation of about 2,500 feet, with very steep sides. I intended to ascend higher and to get directly in the central line of totality, but the river came from the west-northwest and I should have been obliged to travel over one hundred miles, by the windings of the river, to make twenty, and, moreover, that would have landed me in British Columbia. I could not get my instruments and provisions over or upon the mountains, because the Indians are unaccustomed to pack, and no trail led over them.

From July 27th I had fine weather for all preliminary observations of latitude, longitude by chronometer, magnetic declination, dip, intensity, &c.

For three or four days preceding the 7th, we had heavy, cloudy weather. On the morning of the 7th, the weather was cloudy, the barometer rising rapidly, and at 9 a. m. it appeared likely to break away; but soon after that the sky became quite covered with heavy masses of cumuli.

The beginning of the eclipse was lost because of a cloud obscuring the sun for about half a minute. The limb of the moon was very sharply defined, and the outline of the sun was very steady and sharp.

At the times of occultations of spots, clouds intervened. At the meridian passage of the sun

and moon a few drops of rain fell, and the transits of the limbs were lost. The atmosphere continued remarkably steady.

As the eclipse progressed the growing darkness was very marked, but altogether different from that of twilight or moonlight. About the time the sun was half obscured the chief Koh-klúx and all the Indians had disappeared from around the observing-tent; they left off fishing on the river-banks; all employments were discontinued; and every soul disappeared; nor was a sound heard throughout the village of fifty-three houses. Even the everlastingly howling curs seemed to be quieted down. The natives had been warned of what would take place, but doubted the prediction. When it did occur they looked upon me as the cause of the sun's being "very sick and going to bed." They were thoroughly alarmed, and overwhelmed with an undefinable dread.

Two or three minutes before the commencement of totality the clouds broke away directly around the sun, and the crescent was very beautiful to the unassisted eye and in the telescope. In the telescope the borders of the sun and moon were remarkably steady and very sharply defined. In twenty-four years of practice in observing I have rarely, if ever, seen them under such favorable circumstances. I observed them without any shade, and followed the sun's border to the instant of its disappearance. The bright, long, narrow crescent was sharply and regularly defined throughout; the extremities were clear-cut and pointed. As the width and length of the crescent decreased, this same sharpness of outline and regularity of form were maintained until it became a fine line of *living* white; and, shortening rapidly, it disappeared as a very short, fine, distinct line, and not as a star at its disappearance. There was no breaking of this line into points or beads; no wave-motion along it; no disturbance whatever of continuity or regularity of form.

I watched to see whether the last visible edge of the sun would appear projected *upon* the black border of the moon, as I have twice observed α Scorpii projected for 2.5 seconds upon the bright limb of the moon at the occultation of that star, but no such phenomenon presented itself.

In noting the time of commencement of totality, the chronometer was held within ten or twelve inches of me, and I distinctly read the seconds and the minutes, while my aid made the record in lead-pencil, but says it was difficult to read the writing after making the record. We had no artificial light at the station.

Instantly upon the disappearance of the last edge of the sun, the narrow, *bright* white line of the corona took its place, and was as sharply defined and unbroken as the sun's edge had been.

The appearance of the long, narrow line of the sun's border, just before its obscuration, may be described as a curved line of silver at a white heat, glowing and living, yet not dazzling; while the curved line of the corona may, in comparison, be described as a fine line of bright burnished silver, from which the rays of the corona started; it lacked the vividness of the sun-crescent, yet I think an inexperienced observer might have mistaken it for the border of the sun still hanging on with diminished brightness.

The rose-colored flames from the sun's limb were seen before I took my eye from the telescope. After the record of the time of totality, say in less than eight* seconds thereafter, I commenced to note the position, extent, and elevation of these flames; searching the whole circumference of the moon for faint or minute prominences, and noting the appearance and extent of the corona. The flames were not of uniform color, but were marked by dark lines perpendicular to the moon's limb; on the larger flame these dark lines were very distinct. The coloring of these flames was vivid, not tame or dead, and markedly and peculiarly relieved by the black body from which they apparently arose. Their outline was very distinct. To the unassisted eye they were brilliant, unmarked by lines, and showed as only two masses of flame; the two smaller ones showing as a single, long flame of inferior height.

The spectacle was sublime; the solemn feeling with which the growing darkness, the bold, dark mountains, the rush of the swift-flowing river, and the wild surroundings had affected every one gave way to bursts of admiration at this magnificent glory in the heavens.

The corona was not visible around the moon's whole circumference at the earlier period of totality; but after I had established the position, &c., of the flames, it was observed around less than half the circumference, with a faintish glow around the other half, but sufficient to bring out

* I estimate it less than eight seconds, because I observe and record transits of nine seconds apart; and I lost no time here, while the record was made by my aid.

in bold contrast the dark outline of the moon. This may have arisen in part from the cloud which intervened after I had been watching the phenomena about one and a half or two minutes. The extreme height of the rays of the corona was about one-third the diameter of the moon; no waviness was seen in the rays. Mr. Throckmorton reports that to the naked eye the rays appeared to extend beyond the outline of the moon about one-tenth of the moon's diameter, and to be equally bright around the whole disk.*

The annexed sketch (Plate No. 25, Fig. 15) shows the general appearance of the flames, their position, extent, elevation, and color, as closely as I could determine them, and the limit of the corona when my attention was particularly directed to that.

When I found that clouds had hidden the moon from me, I looked up the valley of the Chilkaht, which makes a small angle with the path of totality, and saw, on the northeast flank of the mountain-range on the right bank, the line of the coming light sweeping down rapidly, showing through rifts in the clouds, and beautifully lighting up the snow-filled gulches and crests of the mountains. To the senses, the increasing light after totality was much more rapid than the decreasing light before totality had been, although the clouds were, to all appearances, the same. The natives felt its influence at once, and came from their houses in hundreds; gradually they approached and surrounded the observatory.

A feature of the phenomena of totality was the vivid impression that the dark body of the moon stood out clearly and unmistakably in relief in the space between the observer and the brightness around the obscured body of the sun, and did not lie flat and upon it, as in a picture.

The limited number of my party prevented the observation of magnetic changes. A few meteorological observations were made; little or no change of temperature was appreciable to the senses; and, I think, the sun, occasionally breaking through the clouds, masked any real change. The following observations show the general condition of the temperature August 7, 1869:

	Time.		Thermometer, 1.*	Thermometer, 2.†	Aneroid barometer, 1.	Aneroid barometer, 2.‡
	h.	m.	°	°	in.	in.
Sun in and out	11	15	65.0	61.0	30.19	30.28
Clouds variable	12	00	61.2	59.8	30.20	30.28
Heavy clouds	12	30	57.1	57.0	30.19	30.27
Clouds variable	1	05	54.4	54.6	30.20	30.26
Drops of rain	1	30	57.4	56.8	30.18	30.25
Clouds	2	00			30.20	30.28

* 120 feet south of station; correction for index-error = + 0°.7.
† 63 feet south of station; correction for index-error not known.
‡ Barometers at the station.

Governor William H. Seward and party were on the river, coming up to my station, at the time of the eclipse. As the obscuration advanced the Indians refused to proceed, landed, and fled to the bush, and returned soon after totality. The gentlemen had a fine view of the sun-flames and corona through a break in the clouds, and from their position had an excellent view of the approaching and retreating shadow as it swept down the valley. A second party on the river witnessed the same phenomena. A third party lost totality on account of clouds.

On the steamer Active, lying in Anchor Bay, at the mouth of the Chilkaht, the ladies and gentlemen on board had a view of the whole of totality, and saw Mercury and several stars through breaks in the clouds. From them I obtained sketches of the relative positions of the sun, Mercury, and stars, by plotting the sun on section-paper and letting each person place the planet and stars where he judged that he saw them, using the sun's diameter as a measure of relative distance. It was remarkable how well they agreed; and as they saw stars as small as the 4th magnitude, possibly some of the 4½th magnitude, I have made a sketch (Plate No. 25, Fig. 16) of such as were corroborated, and herewith annex it.

None of these observers saw any break in the continuity of the disappearing or re-appearing edge of the sun; some viewed it through opera-glasses.

* One person, situated in latitude 59° 10′ and longitude 135° 26′ west, that is, in the southern part of the track of totality, noticed that the corona was "wider on the upper half of the sun than elsewhere."

I will endeavor to make a colored sketch of the appearance of totality, although I cannot hope to approach an adequate representation of the beauty which it presented.

I desire specially to commend to your consideration the assistance I received from the temporary aid S. R. Throckmorton, jr., and for the readiness and heartiness with which he entered upon a difficult and dangerous duty.

Very respectfully, yours,

GEORGE DAVIDSON,
Assistant, United States Coast Survey.

Professor BENJAMIN PEIRCE,
Superintendent United States Coast Survey, Washington, D. C.

REPORT ON THE RESULTS OF THE REDUCTION OF THE MEASURES OF THE PHOTOGRAPHS OF THE PARTIAL PHASES OF THE ECLIPSE OF AUGUST 7, 1869, TAKEN AT SHELBYVILLE, KENTUCKY, UNDER THE DIRECTION OF PROFESSOR WINLOCK. BY C. S. PEIRCE, UNITED STATES COAST SURVEY.

WASHINGTON, *September* 3, 1872.

DEAR SIR: In accordance with your instructions, I have discussed the measures of Professor Winlock's photographs of the eclipse of August 7, 1869, taken at Shelbyville, Kentucky. The measures had been made in polar co-ordinates, the origin being a point near the sun's center, readings being taken at equal angular intervals and also on the cusps.

In stating the method of reduction adopted I shall use the following modification of the common Euclidean notation, designed to distinguish between opposite directions of measurement:

$$AB = -BA$$
$$\angle ABC = -\angle CBA$$

Then to connect the signs of lines and angles, it may be assumed that $\frac{AC}{\sin ABC}$ is always *positive*, which will always be possible if we permit the signs of angles which differ only in the length of their legs to differ. Consequently,

$$\frac{AC}{\sin ABC} = \frac{BA}{\sin BCA} = \frac{CB}{\sin CAB}$$

We have also,

$$ABC + BCA + CAB = \circlearrowleft$$

Then, in a right-angled triangle, if $BCA = +\frac{1}{2}\circlearrowleft$

$$ABC + CAB = \tfrac{1}{2}\circlearrowleft$$
$$\sin BCA = +1$$
$$\sin ABC = \cos CAB = \frac{AC}{BA}$$
$$\sin CAB = \cos ABC = \frac{CB}{BA}$$

But if $BCA = -\frac{1}{2}\circlearrowleft$,

$$ABC + CAB = -\tfrac{1}{2}\circlearrowleft$$
$$CBA + BAC = +\tfrac{1}{2}\circlearrowleft$$
$$\sin ACB = +1$$
$$\sin CBA = \cos BAC = \frac{CA}{AB}$$
$$\sin BAC = \cos CBA = \frac{BC}{AB}$$

I shall now put—

O, origin of co-ordinates;
θ, a point on the prime radius;
X, the variable point;
S, the center of the sun.

The first step of the discussion was to assume that for the limb of the sun—

$$XO = a + b\cos 2XO\theta + c\sin 2XO\theta + e\cos XO\theta + f\sin XO\theta,$$

and to calculate the constants of this equation for seventeen photographs. The results are shown in the following table:

No. of photograph.	Shelbyville, sidereal time.	a	b	c	d	e
	h. m. s.					
1	13 27 28.08	10.070	−.004	+.013	−.003	−.010
3	31 52.06	.049	+.013	+.009	−.015	+.005
6	34 06.30	.061	+.004	+.016	+.001	+.031
8	38 46.21	.086	+.006	+.007	−.012	+.007
10	39 19.69	.039	−.003	−.003	+.016	+.0105
13	43 39.27	.058	+.018	−.001	−.023	+.023
16	48 20.34	.041	+.020	+.012	−.008	+.058
21	55 50.19	.059	−.002	+.021	+.005	+.045
37	14 19 42.12	.039	−.004	−.014	+.003	+.015
40	28 18.74	.114	−.007	−.0344	+.0267	−.0217
63	43 28.08	.0882	−.0229	+.0195	−.0140	−.0488
66	45 57.56	10.0869	+.0050	−.0385	−.0391	+.0676
72	15 03 46.99	9.990	−.018	+.016	+.012	−.001
76	13 21.36	10.015	+.034	−.011	−.012	−.028
81	24 01.59	10.005	+.055	+.015	+.048	+.003
82	24 10.32	9.998	+.062	+.010	+.036	−.014
83	26 04.93	9.967	+.055	+.002	+.072	+.003

The next step was to use these results to find whether there was any constant tilt of the photograph-plates with reference to the optical axis of the telescope.

For this purpose, the parallactic angle ZSN was calculated from the ephemeris and the known geographical position. From Mr. Dean's observations of internal contacts at Shelbyville, the ephemeris was corrected, and the position-angles XSN for the cusps were found and corrected for differential refraction. Then, neglecting the difference between XSθ and the observed XOθ (which, however, could easily have been allowed for, if it had been of any consequence), we have—

$$NO\theta = XO\theta - XSN \text{ and } ZO\theta = ZSN + NO\theta$$

Next, from the observations of barometer and thermometer made during the eclipse and the calculated altitudes, the effect of simple refraction and of differential refraction upon the vertical and horizontal diameters of the sun were calculated from Bessel's refraction-tables; and from a preliminary reduction of the measures of the moon's limb on two photographs and approximate value for s—

M, the center of the moon;
Z, the zenith;
N, the north pole;
Y, the foot of a perpendicular let fall from M upon XO;
U, the point in the heavens toward which the photograph faces.

Where it is necessary, values for different photographs will be distinguished by subjacent numbers; values for sun and moon by subjacent ⊙ and ☾; and values derived from the ephemeris and expressed in seconds will have an accent, while values derived from the photographs and expressed in screw-revolutions will be written without an accent. I shall also write—

$R_\odot$ for apparent radius of sun;
$R_☾$ for apparent radius of moon;
s for the number of seconds of arc in one revolution of the micrometer-screw;
k calculated difference of the vertical and horizontal diameters of the sun, when the simple and the differential refractions are allowed for, expressed in screw-revolutions;

was obtained. From these the values of k were found. Then if there were no tilt, we should have—

$$b = -\tfrac{1}{4}k \cos 2\,NO\theta$$
$$c = -\tfrac{1}{4}k \sin 2\,NO\theta$$

This not being the case, we calculate—

$$m = 4b + k \cos 2\,NO\theta$$
$$n = 4c + k \sin 2\,NO\theta$$

and thence,

$$k'=\sqrt{m^2+n^2}$$

$$\omega=\tfrac{1}{2}\ \text{arc}\tan\frac{n}{m}-\text{NO}\theta$$

Then k' will be the value of the maximum elongation of the diameter produced by the tilt, and ω will be the angle which the plane which passes through the photograph and the sun, and is perpendicular to the photograph, makes with the meridian. These values will not be constant in all the photographs on account of the adjustments made in hour-angle. Therefore, I have calculated SU from the formula—

$$k'=2\,\text{R}_{\odot}\ (\sec \text{SU}-1)$$

and then, in the spherical triangle NUS, we have $\angle$NUS, side NS, and side SU known, and thence can calculate $\angle$UNS and side UN. Then the test of the hypothesis of a constant tilt is that UN+NS should be constant and that there should be a moderate range in the values of $\angle$UNS.

On performing the calculation for the above seventeen photographs, I found the result unsatisfactory. The tilt was often considerable, but had no fixed character. I learned that a number of different plate-holders were used, and I suppose they were not true. In the remainder of the discussion I have necessarily supposed that there was no tilt, as the measures are not sufficiently nice, owing to the want of photographic achromatism, to base values of the two tilt-constants on each photograph singly.

The next step was to correct all the measures of both sun and moon on six photographs for the calculated vertical compression of differential refraction and horizontal compression of simple refraction.

It was then assumed that the sun's and moon's limbs, so corrected, were circles. For the former, therefore,

$$\text{XO}=a+e\cos \text{XO}\theta+f\sin \text{XO}\theta$$

The constants were calculated.

For the moon we have MYO, a right angle.

$$\text{XO}=\text{XY}+\text{YO}$$
$$\text{XY}=\text{XM}\cos \text{YXM}$$
$$\text{YO}=-\text{MO}\cos \text{YOM}$$

so that

$$\text{XO}=\text{XM}\cos \text{YXM}-\text{MO}\cos \text{YOM}$$

In order to prevent mistakes about the signs of YXM, geometrical figures were constructed for each photograph and used for reference. The sign changes with the change of XM$-$XO.

We then get, with a few reductions,

$$\text{D}_{\text{XM}}\text{XO}=\sec \text{YXM}$$
$$\text{D}_{\text{MO}}\text{XO}=\tan \text{YXM}\sin(\text{XO}\theta-\text{MO}\theta)+\cos(\text{XO}\theta-\text{MO}\theta)$$
$$\text{D}_{\text{MO}\theta}\text{XO}=-\text{MO}\cos(\text{XO}\theta-\text{MO}\theta)\tan \text{YXM}+\text{MO}\sin(\text{XO}\theta-\text{MO}\theta)$$

But the probable error of a measure of the radius-vector will vary with the inclination of the radius-vector to the normal to the limb; for by far the largest source of error of these measures is the blur of the outline. The error will, therefore, be proportional to the depth of the blur in the line of measurement, and, therefore, to sec YXM. Dividing the equations of condition by this, they become—

$$\text{corr. R}_{☾}+\cos(\text{XO}\theta-\text{MO}\theta-\text{YXM})\ \text{corr. MO}+\text{MO}\sin(\text{XO}\theta-\text{MO}\theta-\text{YXM})\ \text{corr. MO}\theta$$
$$+\ (\text{calc.}-\text{meas.})\ \text{XO}=0$$

In this way, the values of $\text{R}_{☾}$ and MO were obtained from each photograph. By means of the previously obtained e and f, the values of MS were next obtained.

The calculations being made, it was found that the values of the moon's radius, and consequently of the distance of the sun and moon, were quite uncertain, owing to the eccentric position of the origin, which deprived the measures near the cusps of much of their value, and also owing to all the measures being of one side of the moon only. In consequence of this, two of the photographs calculated were entirely rejected, and for the others the following method, confessedly defective, but the best possible under the circumstances, was adopted in the further discussion:

Of the four photographs under consideration, two were taken before totality and two after. I

first found the effect upon MS, which would be produced by fixing the radius of the moon at a slightly different value from that found by least squares. The values of $D R_{☾} MS$ are—

Photograph	$D R_{☾} MS$
37	1.17
40	1.20
63	1.21
66	1.18

It was then assumed that the mean of the four errors of the radius of the moon for the four photographs was zero. Then, taking MS at what it would be, for the earliest and the latest of these photographs, if the values of $R_{☾}$ were corrected, the ephemeris values of (MS)′ give the values of s by the formula—

$$s = \frac{(MS)'_{37} + (MS)'_{66} + \frac{2.35}{4} \Sigma R'_{☾} - 1.17\, R'_{☾\,37} - 1.18\, R'_{☾\,66}}{(MS)_{37} + (MS)_{66} + \frac{2.35}{4} \Sigma R_{☾} - 1.17\, R_{☾\,37} - 1.18\, R_{☾\,66}}$$

Then, finding the corrections of $R_{☾}$, we have—

Photograph.	Corr. $R_{☾}$	Corr. MS.	(MS)′ calc.	(MS′) obs.	Diff.
	r.	r.	″	″	″
37	+.0327	+.0383	466.7	470.8	+4.1
40	—.0279	—.0335	181.9	187.3	+5.4
63	+.0268	+.0324	329.5	322.9	—6.6
66	—.0315	—.0372	414.5	410.2	—4.3

Taking the mean of these differences, or 5″.1, as the ephemeris correction, we have as final residuals—

—1″.0, —0″.3, —1″.5, —0″.8

I conclude that photographs measured in this way are practically of little value for eclipses. I had hoped that the sum of the sun's and moon's radii would be given with accuracy, and by combining it with the values of the differences of the radii found by internal contacts, as follows:

	″
From observations at Bristol,	1.20
Shelbyville,	1.76
Springfield,	1.66
Des Moines,	1.40

that good values of the semi-diameters would be obtained. But not only have the circumstances just narrated entirely destroyed this expectation, but, furthermore, it is evident that for some reason both the sun's and moon's semi-diameters are much too small, as given by the photographs—

Photograph.	$R'_{\odot}$ calc.	$R'_{\odot}$ obs.	$R'_{☾}$ calc.	$R'_{☾}$ obs.
	″	″	″	″
37	947.2	931.2	992.7	975.0
40	947.2	934.8	992.3	980.2
63	947.2	930.7	991.3	974.1
66	947.2	931.8	991.2	979.4

In these observed values of $R'_{☾}$ no correction has been applied. The fact that both sun and moon are too small is, no doubt, to be accounted for by the presence of the corona around the sun. In consequence of this, the most definite line in the blur produced by chromatic aberration about the limb of the sun will be on the inside, while on the limb of the moon the most definite line will be nearer the light part of the photographic negative, that is, further out in reference to the sun.

I append to this report the residuals given by my calculations.

Your obedient servant,

C. S. PEIRCE.

Professor BENJAMIN PEIRCE,

Superintendent of the United States Coast Survey.

Differences of observed and computed radii-vectores for eclipse-photographs Nos. 37, 40, 63, and 66.

Moon.						Sun.					
37 c−o	37 cont'd. c−o	40 c−o	63 c−o	66 c−o	66 cont'd. c−o	37 c−o	37 cont'd. c−o	40 c−o	63 c−o	66 c−o	66 cont'd. c−o
″	″	″	″	″	″	″	″	″	″	″	″
+4.2	+0.7	+0.6	+0.1	−0.7	+2.7	−0.3	−0.4	+0.4	+0.6	−0.9	+0.4
−0.4	+ .4	+2.2	−1.3	+0.1	+2.2	− .7	+1.8	+2.3	− .0	−1.8	+ .4
− .2	− .2	+1.7	−0.2	+1.7	+0.6	− .9	+2.1	+0.7	− .1	−1.1	− .0
− .4	+0.1	+0.4	+2.1	+0.2	−0.6	− .9	+2.3	+ .5	− .6	+0.1	− .3
− .1	−1.8	+ .3	+0.6	+0.0	−0.4	+0.6	+0.8	+ .5	− .7	− .3	− .6
+ .9	−4.2	+ .8	−1.3	+1.6	+1.3	−1.2	− .4	− .0	− .6	− .2	− .7
+ .9	−2.6	+ .0	−1.1	+1.0	+2.4	+0.4	− .7	−0.9	− .2	− .5	− .7
− .4	−4.1	+ .1	−0.6	+0.0	+1.8	−1.4	+ .2	−1.1	+0.5	− .5	−0.3
− .0	+2.0	+ .2	−1.0	+1.0	+1.1	−1.2	+0.5	−0.8	−1.0	+ .2	−1.1
− .9	+2.1	− .2	−0.1	+2.5	−0.2	+1.5	+1.5	− .5	+0.8	+ .9	−2.1
+ .4	+3.5	+0.2	− .3	+3.3	−0.0	−1.0	+2.0	− .4	+ .7	+0.6	−1.7
− .9	+2.0	+1.6	−0.7	+2.5	−0.2	−4.5	+2.4	− .1	− .8	+1.0	−1.5
−0.3	+3.2	+1.2	−1.6	+0.1	+1.5	−2.1	+0.5	+ .4	− .7	+0.5	−0.4
+1.5	+1.6	−0.0	−1.0	−1.8	+0.4	−2.5	− .0	+ .5	+ .7	+0.7	+ .1
+3.4	+1.0	−0.1	+0.3	−1.8	−0.7	−0.5	− .9	− .2	+ .5	+2.0	+ .7
−0.6	+0.8	−1.3	+1.3	−0.6	−1.3	−0.9	− .4	+ .8	+0.5	+0.9	−0.3
−1.3	+1.7	−1.5	+1.8	− .9	−1.6	+1.6	− .9	− .2	+1.8	+0.8	+1.6
−0.1	+3.1	−1.5	+1.0	− .9	−0.5	−1.0	+0.2	− .9	−0.7	+1.8	+0.6
+1.4	+3.0	−1.6	+2.8	+0.6	−1.1	−1.7	+1.8	− .6	+ .1	−0.1	− .4
−0.8	+1.9	−0.8	+2.5	−1.3	−0.9	−0.2	+1.6	+ .6	− .0	− .2	+0.7
−1.2	+3.0	− .5	+1.5	−0.4	−2.0	−0.4	−0.9	− .6	+ .8	+ .6	+1.0
−1.1	+2.2	+0.4	−0.6	−1.3	−0.6	−1.8	− .7	− .3	+ .3	− .1	+0.3
−1.1	+3.0	+2.4	−1.2	−3.1	−1.5	−0.4	+ .2	− .1	− .4	+ .4	+ .5
−0.8	+2.4	−0.2	−0.4	−1.2	−2.4	−1.9	+0.3	+ .1	− .1	+ .1	+ .7
−0.7	+1.9	+2.2	+ .7	+3.1	−0.5	+0.1	−1.1	+ .7	− .9	− .1	− .7
−2.2	+1.4	+0.4	−0.7	−2.2	+1.0	+ .3	+1.9	+ .3	+ .3	− .3	− .0
−0.9	+0.8	−1.0	−2.4	−2.4	+0.7	− .9	+1.1	− .0	−0.7	+ .3	− .4
+ .3	+0.3	−0.8	−2.5	−2.1	−1.4	− .4	+2.1	+ .7	−1.7	+ .8	−0.5
+0.5	−1.7	−1.9	+0.7	−1.7	−0.8	+ .4	−0.4	− .0	+1.2	+0.6	+1.8
+1.1	+0.6	+0.2	+ .6	−0.4	−0.8	+ .5	+1.0	− .0	−1.0	−1.3	+1.8
−2.2	+1.1	+ .8	− .5	−0.9	−2.9	+0.6	+2.0	− .5	−0.7	−1.0	+0.4
−2.4	+0.3	− .0	+ .4	−1.2	−2.7	−1.3	−1.3	+ .7	− .0	−0.7	− .4
−0.0	−0.6	+0.5	+ .1	−1.9	−2.4	−1.4	+0.8	+ .5	+ .2	−1.0	− .7
−1.7	−2.5	−2.6	− .6	−0.9	−1.8	−0.9	− .0	−0.0	− .7	−0.7	−0.5
−2.0	+0.1		+0.9	+1.2	−2.5	+ .2	+0.9		+ .1	− .7	+1.6
−1.4	+0.7		+ .6	+1.2	−1.2	−0.6	−1.2		+ .8	+ .4	−0.2
+0.4	−3.2		+0.0	+0.4	−0.0	+1.3	+1.3		+0.4	+ .3	+1.3
+ .1	−1.3			+0.3	+2.5	+0.2	−3.0			− .6	+0.1
+ .9	−0.1			−1.6	+2.6	+1.1	−1.9			+ .3	+ .2
+ .2	−0.1			−0.7	+2.4	+1.5	+0.4			− .1	−0.2
− .7	+2.2			+1.2	+1.3	+0.8	+ .4			− .1	−1.3
+ .2	+2.5			+1.6	+1.1	+1.0	− .4			− .8	−0.6
− .6	+3.4			+1.6	+1.0	+0.9	−0.3			+ .4	+0.2
−0.8	+1.4			+0.8	+1.2	+1.8	−1.6			+ .3	−1.1
−1.3	+1.5			+2.8	+0.4	+0.7	−0.9			−0.3	−0.1
−0.6	+0.2			+1.6	+0.4	+ .1	+1.3			−1.0	− .1
−0.8	−2.5			+0.3	−1.6	+0.2	+0.7			−0.6	− .3
−2.1	+0.1			+0.8	−0.5	−1.2	−0.9				−0.5
+0.5	+0.8					−0.6	−1.1				
	+2.0					− .7	+1.0				
						+ .5	−0.3				
						− .6	−1.5				
						+ .6	−1.9				
						+0.3					

REPORT ON THE RESULTS OF THE MICROMETRIC MEASURES OF PHOTOGRAPHIC PICTURES OF THE SOLAR ECLIPSE, OF AUGUST 7, 1869, TAKEN AT SPRINGFIELD, ILLINOIS. BY CHARLES A. SCHOTT, ASSISTANT, UNITED STATES COAST SURVEY.

[Mr. Schott's "Report on the results of the micrometric measures of photographic pictures of the solar eclipse of August 7, 1869, taken at Springfield, Illinois," contains a profound discussion of the photographic method as applicable to eclipses and transits. The computations have been conducted with critical regard to all sources of error, and with a minuteness of detail which would not be recommended in the usual discussions of eclipses of the sun. But the results must be regarded as indicating the exceeding value of photographic observations in transits of Venus and Mercury, and their decided superiority in those cases to observations of contact with eye and ear, as hitherto practiced.—B. P.]

MAY 31, 1872.

The necessity of procuring a micrometer suitable for the measure of photographs of the sun, the time spent in connection with the observations, in Europe, of the eclipse of December, 1870, the necessarily laborious task of measuring the photographs, and the lengthy computations required in their discussion were the principal causes of the delay in the presentation of this report. Nearly all the measures and computations were made by myself, at times when least interfering with the ordinary duties of the computing division of the office.

For the measures of the photographs, the Survey procured from Mr. L. M. Rutherfurd, of New York, a delicate micrometer, constructed from his own designs, and under his immediate supervision. This instrument (marked No. 3) was received June 25, 1870, and was immediately tested and adjusted for measures. Those finally retained in the discussion were taken after my return from Sicily.

The principal parts of the Rutherfurd micrometer are two steel screws, $6\frac{1}{4}$ inches in length, and $\frac{1}{2}$ inch in diameter, containing about 48 threads to an inch, and working at right angles to each other; a horizontal, divided circle of 9 inches diameter, with two opposite verniers for angular measures; and a microscope attached to the frame-work, and moved by the two horizontal screws. The microscope is provided with two object-lenses, giving magnifying powers of 10 and 160 nearly. The photograph, or object to be measured, rests on a glass plate, connected with the axis of the horizontal circle. A test-plate for finding the value of a turn and division of the screws is supplied, as well as all necessary appliances for adjusting the parts of the instrument. The circle can be read to 10″; the micrometer-heads are divided into 100 parts, and these again are subdivided into 4 parts, and one-fifth of the distance of the latter may yet be estimated. The probable error of a *single pointing*, on a fine diamond line on the test-plate, with the cross-threads of the microscope, with a power of 10, equals ± 0.0025 turn (nearly $\frac{1}{19000}$ of an inch); with a power of 160, it equals ± 0.0006 turn (nearly $\frac{1}{80000}$ of an inch), showing the probable error of pointing to be inversely proportional to the square root of the magnifying-power. From a small number of measures, I find the value of one turn of the upper screw (its axis may be brought into the vertical plane passing through the axis of the circle) equal to 0.020835 ± 0.000001 inch, at a temperature of 86° Fahrenheit; and one turn of the lower screw, equal to 0.020778 ± 0.000001 inch, at 85° Fahrenheit. In the metric system these results are:

$$1 \text{ turn of upper screw at } 30^\circ 0 \text{ C.} = 0^{mm}.52921 \pm 0^{mm}.00002$$
$$1 \text{ turn of lower screw at } 29^\circ.4 \text{ C.} = 0^{mm}.52776 \pm 0^{mm}.00003$$

The values of a turn in different parts of the screws are sensibly equal. For the measures of the eclipse negatives a very moderate degree of magnifying-power suffices on account of the imperfect definition of the edge of the film of the collodion, due to granulation, and a power of 10 was found advantageous for judging of the most probable position of the outline. In the Springfield photographs the image of the sun is nearly two-thirds of an inch in diameter ($17^{mm}.25$). These photographs (as already stated, in my first report of October 4, 1869) were made by Mr. J. W. Black, of Boston; the plates were placed in the focus of the object-glass, and the time-record was obtained automatically by the breaking of a galvanic current acting upon the pen of a chronograph; the time of exposure was estimated at one-thirtieth of a second. Before measuring the photographs the

micrometer was carefully adjusted;* a few trials showed that measures of the chords (or distances between cusps) were of no value, nor were measures founded upon the width of the segment cut out by the projection of the lunar disk near the times of the contacts of any use for accurate work. The unequal spreading of the lighter over the darker surfaces, and the absence of a fixed scale for all the photographs may be considered as the principal causes of the failure of these modes of measures.

In accordance with the method adopted for the treatment of the measures of the Shelbyville photographs by Mr. Charles S. Peirce, it was supposed that the undue spreading of light would increase the photographic radius of the sun as much as it would diminish that of the moon, and consequently would leave the distance of their centers undisturbed; and, further, that the scale-value may be obtained with the assistance of the known tabular motions (supposed correct) of the sun and the moon during the brief interval of the eclipse. Uniformity of treatment in measures and method of discussion was highly desirable, and the Springfield photographs were consequently submitted to the same process as those taken at Shelbyville; it will therefore suffice to refer the reader, for the full exposition of the method, to the report of Mr. Charles S. Peirce, on the result of the photographic operations conducted at the latter place.

In accordance with this method, six photographs were selected for measure (numbered hereafter from I to VI), the first and last being designed principally to furnish the scale value, and the others the corrections to the tabular difference of right ascension and declination of sun and moon. They are also selected symmetrically with respect to the middle of the eclipse, presenting three nearly equal and opposite phases. In photographs I and VI, the moon's center is projected about one-fourth of its radius outside the sun's limb; in II and V, it falls nearly in the middle of the sun's radius; and in III and IV, it approaches a little closer to the sun's center. The process of measuring may be briefly explained as follows: The photograph is placed nearly centrally on the glass plate, collodion side up, or facing the microscope, and focused. Next, the intersection of the threads is brought exactly over the center of the horizontal circle, or in its vertical axis produced, and the readings of the two screws in this position are noted. This was effectively done by means of four successive pointings, in azimuths 90° apart, on a small but well-defined speck selected at a short distance from the axis. The process is repeated until satisfactory. The microscope is then left untouched until the measures are completed and the readings of the center have again been verified. Each photograph is centered over the sun's center, and tested by revolving the circle, when the sun's limb must be kept bisected by the threads. All measures are taken with the upper screw, and with nearly the same part of the screw, the lower screw remaining at the reading of centering. In making the pointing, the last motion given is always in the same direction, to avoid any loose action.

The following record will serve as a specimen of the measures:

January 10, 1872. Photograph at $13^{h}\ 56^{m}\ 32^{s}.58$ (designated II). C. A. S., observer. Temperature, 66° Fahrenheit.

	Circle.	Up. screw.	Mean.	Low. screw.	Mean.
For centering:		t.		t.	
	180°	85.524		77.639	
	270	84.760	84.638	78.645	77.778
	0	83.752	84.644	77.917	77.757
	90	84.528		76.870	
		Axis,	84.641	Axis,	77.768
Cusps:	193°04′	100.935	Lower.		
	34 25	.853	Upper.		
	193 06	.940			
	34 20	.868			

* The several operations may be thus briefly stated: The level is adjusted; the axis of the horizontal circle is set vertical; the glass disk, or support of the object to be measured, is leveled; the sliding-frames of the two screws are made to move horizontally; the indices of the screw-heads are placed on zero, when a whole division of the linear scale coincides with index-lines; the threads of the microscope are focused and collimated or centered; and the screws are made to move at right angles to each other, for which purpose the graduation of the circle is made use of.

Measures.

Sun's limb.		Moon's limb.	Sun's limb.		Moon's limb.
Circle.	Upper screw.	Upper screw.	Circle.	Upper screw.	Upper screw.
°	t.	t.	°	t.	t.
194	101.018	100.613	250	100.998	93.739
	.023	.640		.998	.723
	.023	.608		.991	.731
200	100.998	99.568	260	100.962	93.153
	1.020	.574		.994	.190
	1.022	.512		.995	.133
210	101.005	97.875	270	100.993	92.838
	0.995	.935		.972	.842
	0.980	.898		.997	.844
220	100.973	96.570	280	100.993	92.622
	.996	.540		.973	.568
	1.002	.524		.991	.573
230	100.980	95.408	290	101.031	92.514
	.986	.408		.011	.503
	.978	.430		.027	.483
240	100.953	94.532	300	101.042	92.520
	.956	.512		.013	.493
	.953	.463		.020	.525
			etc.	etc.	etc.

These measures are continued for every ten degrees of azimuth, and conclude with-

°	t.	t.
30	101.027	100.023
	.053	99.981
	.013	100.013

Centering re-examined by a different spot.

	Up. sc.		Low. sc.	
°	t.		t.	
0	84.845		77.356	
90	.998	84.649	77.938	77.741
180	.453	84.643	78.126	77.750
270	.288	———	77.563	———
	Axis,	84.646		77.746
Mean adopted,		84.644		

The representation of the individual measures of the sun's limb on each of the six photographs selected, by means of an expression of the form—

$$r = a + b\cos 2\vartheta + c\sin 2\vartheta + e\cos\vartheta + f\sin\vartheta$$

and, with application of the method of least squares, led to the following results:

Phot.	Sprg. sid. time.			Expression for the sun's limb.
	h.	m.	s.	t.
I	13	27	47.33	$r = 16.3092 + .0113\cos 2\vartheta - .0690\sin 2\vartheta + .0132\cos\vartheta + .0087\sin\vartheta$
II		56	32.58	$16.3851 + .0264\cos 2\vartheta - .0256\sin 2\vartheta + .0152\cos\vartheta + .0150\sin\vartheta$
III	14	00	22.24	$16.3030 + .0555\cos 2\vartheta - .0503\sin 2\vartheta - .0619\cos\vartheta - .0975\sin\vartheta$
IV		25	40.71	$16.3564 - .0181\cos 2\vartheta - .0276\sin 2\vartheta - .0613\cos\vartheta + .0352\sin\vartheta$
V		28	50.59	$16.3448 + .0299\cos 2\vartheta + .0667\sin 2\vartheta - .0089\cos\vartheta - .0850\sin\vartheta$
VI		53	08.04	$16.2334 - .0125\cos 2\vartheta + .0509\sin 2\vartheta - .0666\cos\vartheta + .0126\sin\vartheta$

The following table contains the comparison of the measured (observed) and computed (by above formulæ) radii-vectores; the differences have been converted into seconds of arc by the approximate relation, 1 turn = 58″.

Results of comparison of measured and computed radii-vectores of the photographed sun.

	Differences, Observed—Computed.						
	I.	II.	III.	IV.	V.	VI.	
	″	″	″	″	″	″	
	+ .5	− .1	.0	− .5	+ .5	+ .7	
	− .9	− .1	+ .9	+ .1	− .6	− .1	
	− .2	− .3	−1.4	+ .3	.0	− .2	
	+ .6	+ .3	− .4	+ .7	− .3	.0	
	− .3	+ .2	+1.9	.0	+1.5	− .2	
	+1.6	−1.1	− .1	− .6	−2.1	+ .3	
	+1.0	+1.3	−1.3	− .5	+ .9	− .4	
	− .7	+ .3	− .2	− .6	−1.0	− .9	
	− .3	− .1	−1.5	+ .2	+1.3	+ .6	
	−1.1	− .9	+2.4	+ .6	+ .9	+ .3	
	+ .1	+ .4	+1.2	+ .6	− .3	+ .2	
	.0	− .5	+1.0	+ .7	−1.3	+ .3	
	− .6	+ .5	−1.4	−1.6	− .5	− .3	
	+ .8	+ .1	−2.0	− .3	+ .9	+ .3	
	+1.0	− .6	−1.2	+ .7	+ .2	− .3	
	+ .9	− .7	+1.0	+ .2	− .3	+ .2	
	−1.0	+ .6	+1.7	− .7	.0	+ .4	
	− .2	+ .5	+ .2	+ .4	+ .1	−1.0	
	− .1	+ .2	− .2	− .2	− .5	− .4	
	− .6	+ .1	− .5	+ .2	+1.0	+ .8	
	+ .5	− .6			− .6	− .6	
	− .4					+ .6	
	.0					.0	
	.0					− .1	
	+ .9					+1.1	
	− .9					− .6	
	+ .2					− .6	
Probable error of 1 measure,	± .5	± .4	± .9	± .5	± .7	± .4	Average value, ±0″.5.

The above residuals are chiefly due to irregularities in the sclar outline (difference of chemical action) and to the indefiniteness of the collodion outline caused by granulation. The variations noticed in the several values of r are also mainly due to the same causes, in addition to effects of difference in the condition of the atmosphere and in changes of refraction at the times of exposure. At the time of the first photograph the sun's altitude was nearly 30°, and at the time of the last photograph nearly 13¾°.

The elliptical outline of the photographed sun, as given by the co-efficients of the terms containing the cosine and sine of the double angle, is compounded of that produced by the refraction and by any tilt in the plate, that is, by any want of perpendicularity of the face of the plate to the line joining the station and the sun. To correct for either deviation, we must know the value of the angle ϑ for the vertex and for the north point; and since there is no fiducial line on the Springfield photographs, it became necessary to compute from the data of the ephemeris the position-angle of the cusps, for which ϑ is known by measure, and then obtain the value of ϑ_v and ϑ_N by calculation. It is, however, desirable to use a corrected ephemeris, the result of the reduction of the "eye and ear" observations of the four contacts at some stations selected as the most promising. This will at the same time afford means of comparing the results by the ordinary and by the photographic methods. In the following paragraph, Chauvenet's notation (as given in his Spherical and Practical Astronomy, volume 1, chapter on Eclipses) will be used for convenience' sake, and the computed tabular constants required in the computation will be given in full, to assist those who may be engaged in the calculation of the large number of observations of this eclipse.

Reduction and results of the observations by the ordinary or "eye and ear" method of the four contacts of the eclipse recorded by the Coast Survey parties at Bristol, Tennessee, under Assistant R. D. Cutts; at Springfield, Illinois, immediately under the Superintendent; and at Des Moines, Iowa, under Assistant J. E. Hilgard.

At these stations* the latitudes and longitudes were carefully determined, the latter telegraphically. The revised values are given further on.

General data of the elements of the eclipse of August 7, 1869.

From the American Ephemeris.

	h.	m.	s.
Washington mean time of conjunction in R. A.	4	37	44.6
Washington west of Greenwich	5	08	12.1
Greenwich mean time of conjunction	9	45	56.7

EPHEMERIS.

	MOON.			SUN.		
Gr. M. T.	α	δ	π	α'	δ'	log r'
h.	h. m. s.	° ′ ″	′ ″	h. m. s.	° ′ ″	
7	9 04 14.74	+17 18 11.2	60 18.84	9 10 46.91	+16 16 45.41	0.0059332
8	06 46.18	10 50.1	20.00	10 56.46	16 03.05	303
9	09 17.52	03 21.65	21.14	11 06.01	15 20.66	274
10	11 48.75	16 55 45.9	22.25	11 15.56	14 38.25	245
11	14 19.87	48 02.9	23.34	11 25.11	13 55.81	215
12	16 50.87	40 12.7	24.40	11 34 66	13 13.34	185
13	19 21.75	32 15.35	25.44	11 44.21	12 30.84	155

Assumed values: $\pi_0 = 8''.87$, $k = 0.2723$, $H = 960''$

$$\log(\sin H + k \sin \pi_0) = 7.6689359$$
$$\log(\sin H - k \sin \pi_0) = 7.6667505$$

General tabular results.

Gr. M. T.	a	d	Exterior contact.		Interior contact.	
			l	log i	l	log i
h.	° ′ ″	° ′ ″				
7	137 41 57.83	+16 16 36.48	0.535152	7.664059	−0.010775	7.661873
8	44 15.95	15 55.09	5136	62	0791	76
9	46 34.08	15 13.68	5096	65	0831	79
10	48 52.20	14 32.27	5031	67	0897	81
11	51 10.32	13 50.85	4945	69	0980	83
12	53 28.45	13 09.42	4924	72	1101	86
13	55 46.57	12 27.97	4684	75	1240	89

Gr. M. T.	x	Δ_1	Δ_2	Δ_3	y	Δ_1	Δ_2	Δ_3
h.								
7	−1.555580	+0.562401			+1.027198	−0.114429		
8	−0.993179	487	+ 86		0.912769	4747	−318	
9	−0.430692	505	+ 18	−68	0.798022	5060	−313	+ 5
10	+0.131813	469	− 36	−54	0.682962	5361	−301	+12
11	+0.694282	369	−100	−64	0.567601	5662	−301	0
12	+1.256651	220	−149	−49	0.451939	5944	−282	+19
13	+1.818871				0.335995			

* Shelbyville, Kentucky, would have been taken in had the geographical position been available. The selection of the other two stations was determined by their extreme position in the line of totality and their well-known longitudes.

General tabular results—Continued.

Greenwich M. T.	x'	log x'	y'	log y'	μ_1
h.					° ′ ″
7	+0. 562464	9. 750095	−0. 114745	*n*9. 059734	103 38 00. 37
8	496	120	4903	60331	118 38 10. 05
9	505	126	5060	60924	133 38 19. 77
10	497	120	5209	61486	148 38 29. 47
11	469	098	5361	62059	163 38 39. 18
12	419	060	5511	62623	178 38 48. 95
13	353	009	5656	63168	193 38 58. 68

$$T_0 = 10^{h}, \quad \left\{ \begin{array}{ll} x = +.0.131813 + x'\tau, & \mu' = 54009''.72 \sin 1'' \\ y = +\ 0.682962 + y'\tau, & \log \mu\ = 9.418047 \end{array} \right.$$

Application of preceding results to observations at Bristol, Tennessee ; Springfield, Illinois ; and Des Moines, Iowa.

Eclipse-station.	Bristol.	Springfield.	Des Moines.
ϕ=latitude	36° 35′ 49″. 10 ±0″. 20	39° 49′ 02″. 50 ±0″. 07	41° 35′ 04″. 81 ±0″. 07
ω=longitude west of Greenwich ..	5*h.* 28*m.* 44*s.* 90 ±0*s.* 28 82° 11′ 13″. 50 ±4″. 2	5*h.* 58*m.* 33*s.* 62 ±0*s.* 26 89° 38′ 24″. 23 ±3″. 9	6*h.* 14*m.* 29*s.* 04 ±0*s.* 25 93° 37′ 15″. 60 ±3″. 7
Elevation above sea................	536 meters	150 meters	254 meters ....

Local mean times of observed contacts.

	h. m. s.		*h. m. s.*		*h. m. s.*	
First contact..........	4 43 52. 6	(C.)	4 04 57. 0	(S.)	3 43 06. 9	(H.)
First inner	5 41 21. 1	"	5 05 32. 4	"	4 45 29. 7	"
Second inner..........	5 43 53. 3	"	5 08 21. 1	"	4 48 24. 8	"
Last contact	6 36 40. 0	"	6 03 45. 4	"	5 45 24. 0	"

L t $\omega' + \nu\gamma = \Omega$, where ω' = true longitude; then,

For Bristol—

$$\begin{array}{rrrrrrr} & h.\ m.\ s. & & & & & \\ \Omega = & +\ 5\ 28\ 29.4 + 0.206\,\vartheta & -\ 1.743\,\pi\,\Delta k & -\ 1.743\,\dfrac{\Delta H}{r'} & +\ 0.508\,\Delta\,\pi & +\ 0.490\,\pi\,\Delta e^2 \\ & 35.2 + 0.036 & -\ 1.731 & +\ 1.731 & +\ 0.669 & +\ 0.423 \\ & 36.6 + 0.344 & +\ 1.765 & -\ 1.765 & +\ 1.411 & +\ 0.558 \\ & 42.1 + 0.170 & +\ 1.739 & +\ 1.739 & +\ 1.490 & +\ 0.476 \end{array}$$

For Springfield—

$$\begin{array}{rrrrrrr} & h.\ m.\ s. & & & & & \\ \Omega' = & +\ 5\ 58\ 14.8 + 0.225\,\vartheta & -\ 1.746\,\pi\,\Delta k & -\ 1.746\dfrac{\Delta H}{r'} & +\ 0.345\,\Delta\,\pi & +\ 0.518\,\pi\,\Delta e^2 \\ & 22.8 + 0.208 & -\ 1.743 & +\ 1.743 & +\ 0.448 & +\ 0.530 \\ & 23.2 + 0.203 & +\ 1.743 & -\ 1.743 & +\ 1.410 & +\ 0.528 \\ & 29.7 + 0.185 & +\ 1.741 & +\ 1.741 & +\ 1.430 & +\ 0.523 \end{array}$$

For Des Moines—

$$\begin{array}{rrrrrrr} & h.\ m.\ s. & & & & & \\ \Omega'' = & +\ 6\ 14\ 14.0 + 0.235\,\vartheta & -\ 1.747\,\pi\,\Delta k & -\ 1.747\dfrac{\Delta H}{r'} & +\ 0.240\,\Delta\,\pi & +\ 0.526\,\pi\,\Delta e^2 \\ & 17.7 + 0.430 & -\ 1.784 & +\ 1.784 & +\ 0.214 & +\ 0.646 \\ & 18.2 - 0.001 & +\ 1.731 & -\ 1.731 & +\ 1.481 & +\ 0.444 \\ & 21.1 + 0.188 & +\ 1.741 & +\ 1.741 & +\ 1.386 & +\ 0.542 \end{array}$$

The following weights, based on experience, have been assigned to the equations, in accordance with the circumstances, more or less favorable, attending the observations of the several contacts: To first equation at each station, the weight 1; to second and third equations, the weight 4; and to last equation at each station, the weight 2.

The normal equations, with consideration of weights, are as follows:

$$
\begin{array}{rrrrrrr}
0 = - & 3.17 + 3.113\,\vartheta - & 6.758\,\pi\,\Delta k + & 3.202\,\frac{\Delta\,\mathrm{H}}{r'} - & 4.058\;\Delta\,\pi + & 1.416\,\pi\,\Delta\,e^2 \\
0 = + & 563.14 - 6.758 & + 549.857 & - 258.339 & + 158.413 & - 2.784 \\
0 = + & 386.22 + 3.202 & - 258.339 & + 549.593 & - 70.463 & + 2.610 \\
0 = + & 164.73 - 4.058 & + 158.413 & - 70.463 & + 47.264 & - 1.741 \\
0 = + & 0.53 + 1.416 & - 2.784 & + 2.610 & - 1.741 & + 0.656
\end{array}
$$

$$
\therefore \left\{
\begin{array}{rl}
\vartheta & = - 1''.224 + 0.696\;\Delta\,\pi - 0.456\,\pi\,\Delta\,e^2 \\
\pi\,\Delta\,k & = - 1''.753 - 0.284\;\Delta\,\pi - 0.002\,\pi\,\Delta\,e^2 \qquad [\Delta\,k = - 0.00048] \\
\frac{\Delta\,\mathrm{H}}{r'} & = - 1''.520 - 0.009\;\Delta\,\pi - 0.003\,\pi\,\Delta\,e^2 \qquad [\Delta\,\mathrm{H} = - 1''.54]
\end{array}
\right.
$$

and, by substitution, into equations Ω, Ω', Ω'',

For Bristol—

	h. m. s.			w.
$\Omega =$	+ 5 28 34.86	+ 1.162 $\Delta\,\pi$	+ 0.405 $\pi\,\Delta\,e^2$	1
	35.56	+ 1.170	+ 0.405	4
	35.77	+ 1.165	+ 0.402	4
	36.20	+ 1.098	+ 0.390	2

For Springfield—

	h. m. s.			w.
$\Omega' =$	+ 5 58 20.23	+ 1.014 $\Delta\,\pi$	+ 0.423 $\pi\,\Delta\,e^2$	1
	22.96	+ 1.072	+ 0.433	4
	22.54	+ 1.072	+ 0.437	4
	23.77	+ 1.049	+ 0.431	2

For Des Moines—

	h. m. s.			w.
$\Omega'' =$	+ 6 14 19.43	+ 0.916 $\Delta\,\pi$	+ 0.427 $\pi\,\Delta\,e^2$	1
	17.59	+ 1.004	+ 0.449	4
	17.80	+ 1.004	+ 0.446	4
	15.17	+ 1.007	+ 0.448	2

Substituting the known longitudes, we find—

From observations at Bristol, $\nu\,\gamma = - 9^s.21 + 1.154\;\Delta\,\pi + 0.401\,\pi\,\Delta\,e^2$

From observations at Springfield, $\nu\,\gamma = - 10^s.91 + 1.063\;\Delta\,\pi + 0.433\,\pi\,\Delta\,e^2$

From observations at Des Moines, $\nu\,\gamma = - 11^s.65 + 0.997\;\Delta\,\pi + 0.446\,\pi\,\Delta\,e^2$

There being an insufficiency of range, no correction to the tabular values of the moon's parallax and to the earth's compression can be had from the equations. We find by addition and division—

$$\nu\,\gamma = - 10^s.59 + 1.071\;\Delta\,\pi + 0.427\,\pi\,\Delta\,e^2$$

which leaves the following differences of $\Omega + \nu\,\gamma$, at Bristol, $- 1^s.38$; at Springfield, $+ 0^s.32$; and at Des Moines, $+ 1^s.06$, quantities, which include small outstanding defects in the adopted longitudes, but which are principally due to incidental defects in the observed times of contacts. We also have—

$$\Delta\,(\alpha - \alpha') = - 6''.52 + 0.63\;\Delta\,\pi \text{ and}$$
$$\Delta\,(\delta - \delta') = + 0''.03 + 0.12\;\Delta\,\pi$$

If we suppose the tabular right ascension (α') and declination (δ') of the sun, as given in the American Ephemeris, to be correct, the moon's tabular right ascension requires to be diminished by 6''.5 but its latitude may be taken as very nearly correct. In the subsequent computation I introduced $\Delta\,\alpha = - 0^s.43$ and $\Delta\,\delta = 0$.

Resuming the discussion of the Springfield photographs, the micrometric measures require to be corrected for refraction and tilt of plate. The contraction of the vertical diameter of the sun by refraction is as follows: 1''.99, 2''.89, 3''.04, 4''.67, 4''.95, and 8''.40 for the photographs I to VI respectively, and the contraction of the horizontal diameter 0''.25. The sun's and moon's parallax in right ascension and declination and the parallactic angle together with the distance and position-angle of the line joining the centers of the sun and the moon were next computed by means of the corrected ephemeris. The last-named quantity was equated with the mean of the values of the angle ϑ for the cusps, which gave ϑ_{Y} and ϑ_{X}.

We have—

Phot.	Parallactic angle. q	App. dist. ⊙ and ☾.	App. position. Angle from N. to E.	ϑ_N	ϑ_V	
	° ′ ″	″	° ′	° ′	° ′	
I	52 59 04	1425.1	− 71 10.0	204 10	151 11	The angle ϑ in the measures counts from N. to W.
II	53 06 52	528.4	− 71 30.8	42 13	349 06	
III	53 05 40	406.3	− 71 34.5	307 47	254 41	
IV	52 45 38	418.9	+108 28.5	72 49	20 03	
V	52 41 42	524.2	+108 24.9	179 01	126 19	
VI	52 01 28	1348.0	+108 06.6	198 00	145 58	

Each individual measure of the sun's limb was then corrected for simple and differential refraction, and the same was done for the measures of the moon's limb, with the addition of a correction to the direction (ϑ) for effect of differential refraction. The hypothesis for tilt of plates was next examined, and the direction of maximum elongation (ω) and the amount of inclination (i) for each of the plates, including one intermediate between I and II, were found as follows:

$\omega =$ 116°.5	140°.4	118°.3	Mean, 125°
$i =$ 7°.8	6°.2	6°.2	6°.7

for I, I½, and II, and

$\omega =$ 210°.0	235°.7	212°.7	206°.1	Mean, 216°.1
$i =$ 7°.1	3°.5	6°.5	3°.9	5°.3

for III to VI.

Each measured distance was accordingly corrected for tilt (the mean values for the respective plates being used). No special adjustment had been made to insure the proper position of the plates beyond setting the frame of the camera perpendicular to the axis of the telescope.

The measured radii-vectores, thus increased for effect of simple and differential refraction and diminished for effect of tilt, were next tabulated. The results for photograph II are given as a specimen:

Photograph II.

Sun's outline.				Moon's outline.			
ϑ	Measured rad.-vector.	Same corr'd for refrac.	Same corr'd for tilt.	Corr'd ϑ for diff. ref.	Measured rad.-vector.	Same corr'd for refrac.	Same corr'd for tilt.
°	t.	t.	t.	° ′	t.	t.	t.
194	16.377	16.398	16.308	193 58.4	15.976	15.997	15.909
200	.369	.388	.308	199 58.2	14.907	14.925	14.852
210	.349	.365	.305	209 58.0	13.250	13.272	13.223
220	.348	.360	.319	219 58.1	11.901	11.910	11.880
230	.337	.346	.323	229 58.3	10.771	10.777	10.762
240	.310	.316	.306	239 58.6	9.858	9.862	9.856
250	.352	.356	.354	249 59.1	9.087	9.090	9.089
260	.340	.344	.344	259 59.6	8.515	8.517	8.517
270	.343	.348	.342	270 00.1	8.197	8.200	8.197
280	.342	.348	.331	280 00.5	7.944	7.947	7.939
290	.379	.388	.355	290 00.8	7.856	7.861	7.845
300	.381	.394	.341	300 01.0	7.869	7.875	7.850
310	.415	.431	.359	310 00.9	8.004	8.012	7.977
320	.419	.439	.349	320 00.7	8.340	8.350	8.304
330	.416	.438	.335	330 00.4	8.765	8.776	8.720
340	.419	.443	.332	340 00.0	9.376	9.390	9.326
350	.442	.466	.353	349 59.5	10.158	10.173	10.103
0	.436	.460	.353	359 59.0	11.146	11.162	11.089
10	.422	.444	.348	9 58.6	12.380	12.397	12.324
20	.410	.429	.349	19 58.2	13.817	13.833	13.765
30	.387	.403	.343	29 58.1	15.362	15.377	15.320
	Mean........	....	16.3360				

The conditional equations expressive of the sun's outline were next re-formed, and a second or improved value for the eccentricity of measure was found; these new values for each of the photographs are as as follows:

Photograph.	Spr. sid. time.					
	h.	*m.*	*s.*		*t.*	
I...............	13	27	47.33	$r_\odot$ =	16.2560 + 0.0079 cos ϑ	+ 0.0224 sin ϑ
II...............	13	56	32.58		.3262 + 0.0214	− 0.0118
III...............	14	00	22.24		.2873 − 0.0618	− 0.0756
IV...............	14	25	40.71		.3399 − 0.0751	+ 0.0249
V...............	14	28	50.59		.3362 − 0.0184	− 0.0747
VI...............	14	53	08.04		.2415 − 0.0642	+ 0.0224
Mean.......	....	....	....	$r_\odot$ =	16.298	

After correcting the preceding radii-vectores for eccentricity by means of the above equations, the remaining deviations from a circular outline of the sun are presented in the annexed table. In another arrangement the angles were all expressed, counting from the north point (round by west), and the deviations from a circle in different photographs for the *same* (or nearly the same) point of the limb were compared; but beyond an occasional coincidence in sign and quantity, no marked feature was noticed (in part, no doubt, due to solar rotation).

Deviations of the sun's photographed outline from a circle, after corrections for refraction, tilt, and eccentricity had been applied.

[+ indicates greater radius than the mean value].

Photograph—					
I.	II.	III.	IV.	V.	VI.
″	″	″	″	″	″
+2.8	.0	−1.7	+ .8	− .8	+1.1
+ .8	− .1	+ .1	+ .9	−1.4	+ .5
+ .9	− .5	−1.5	+ .6	− .4	+ .5
+1.0	+ .1	− .1	+ .5	− .9	+ .6
−1.0	+ .1	+2.6	− .6	+1.9	+ .3
+ .9	−1.1	+ .9	−1.3	−1.4	+ .6
− .1	+1.4	− .5	−1.4	+1.7	− .3
−2.0	+ .6	+ .7	−1.3	− .5	−1.2
−1.7	+ .2	− .9	− .2	+2.0	+ .1
−2.4	− .6	+2.7	+ .5	+1.4	− .3
− .7	+ .6	+ .9	+ .9	− .1	− .8
− .5	− .3	+ .4	+1.1	−1.4	− .5
− .5	+ .6	−2.2	− .9	− .8	−1.0
+1.3	− .1	−2.9	+ .5	+ .4	− .1
+1.9	− .9	−2.1	+1.3	− .3	− .3
+2.1	−1.0	+ .4	+ .6	− .8	+ .4
+ .2	+ .2	+1.5	− .5	− .4	+ .9
+ .9	+ .3	+ .5	+ .2	− .1	− .3
+ .7	+ .2	+ .6	− .9	− .3	+ .4
− .1	+ .4	+ .9	− .9	+1.6	+1.7
+ .6	+ .2			+ .2	+ .2
− .7					+1.3
− .7					+ .2
− .9					− .2
− .2					+ .4
−1.9					−1.6
− .5					−2.1

It was expected that the successive photographic radii would diminish (show less spread) with the decrease in the sun's altitude, though the smallest value is the last one, evidently other disturbing influences were at work.

We now come to the determination, from the measured directions and distances of points on the moon's outline, of the moon's photographic radius for each of the plates. These measures, taken

from the known eccentric position, and corrected for refraction and tilt, furnish conditional equations of the form—

$$\delta\mathrm{R}+\cos\,(\vartheta-\vartheta_{☾}-\beta)\;\delta\Delta+\Delta\,\sin\,(\vartheta-\vartheta_{☾}-\beta)\;\delta\vartheta_{☾}+n=o$$

where δ R, $\delta\Delta$, and $\delta\,\vartheta_{☾}$ are corrections to assumed values of the moon's radius, to the assumed distance of the origin of co-ordinates (near the sun's center) and the center of the moon's outline, and to the direction of the moon's center from the same origin, respectively. Here the moon's outline is supposed circular, and the weights to each measure depend on the inclination of the direction of measure to the direction of the moon's radius (produced) at that point, and which inclination is equal to the angle β. The measure of the maximum width of the moon's projection upon the sun for photographs I and VI, and of the maximum width of the crescent of light for photographs II, III, IV, and V, have the unit weight; all others have less. Each photograph thus furnished three normal equations determining the moon's radius (R), distance (Δ), and the direction ($\vartheta_{☾}$) from the origin of co-ordinates. The resulting series of remaining differences of computed and measured distances I have thought capable of still further improvement, and the values finally adopted are given below. The necessary introduction of weights to the measures on account of blur of outline in a measure opposed the condition which otherwise best determines the radius, thus especially in photographs I and VI, where the moon's outline is convex to the sun's center; the greater the angle $\vartheta-\vartheta_{☾}$ (also the greater the angle β), the better the condition for the determination of R, but the worse the reliability of the measure itself, hence the necessity of applying to it the smaller weight. We find—

Photograhs.	$\vartheta_{☾}$		Λ	R	Sum of ☉'s and ☾'s photographic radii.	Mean.
	°	′	t.	t.		
I	275	17	23.699	16.421	32.677	
II	113	27	9.105	16.925	33.251	33.131
III	19	10	6.955	16.775	33.062	
IV	324	16	7.145	16.800	33.140	
V	70	40	8.948	16.733	33.069	
VI	89	45	24.297	17.980	34.221	

By means of these values, the computed and measured (corrected for refraction and tilt) radii-vectores to the moon's photographic outline exhibit the following differences (C—O) converted into seconds of arc:

I.	II.	III.	IV.	V.	VI.
″	″	″	″	″	″
+0.7	−3.7	−2.4	−0.9	−2.0	−3.4
−1.7	−1.2	+2.3	+4.1	+3.5	0.0
+0.5	+2.8	+2.4	+1.3	−0.7	+4.2
+0.7	+1.8	−1.4	−2.7	+0.9	+2.5
−0.3	+0.4	−0.5	+0.2	−0.2	+1.8
+1.2	−0.8	+2.6	+2.0	−0.5	+2.4
+0.5	+1.6	+5.7	+1.3	+0.2	+1.6
−2.6	+2.9	+2.6	−3.0	−1.0	−0.3
+1.6	−1.0	−0.3	−0.4	−3.1	+1.3
	−0.2	−0.5	+3.8	−1.4	−0.4
	−1.0	+0.5	−1.4	+2.3	−1.7
	−0.2	+0.5	−4.1	+0.7	−0.8
	+1.2	−0.9	−3.3	+1.0	+0.5
	−1.2	−1.7	−2.1	−1.6	+1.2
	−0.3	+0.2	−3.1	−2.7	+1.6
	−0.4	−1.3	−0.2	−1.5	−0.8
	+0.2	+0.6	+0.1	−0.3	+3.2
	+0.3	+0.2	−0.1	−1.3	+2.4
	−1.2	+1.8	+3.7	+1.0	−3.2
	−2.3	+0.6	+0.2	+3.2	
	+1.1			−1.4	

These differences are necessarily greater than the corresponding differences referring to the solar outline, on account of the actual irregularities in the moon's figure. The values for the moon's photographic radius by pictures I and VI are evidently defective, the cause of which is readily traceable to the limited length of lunar arc projected upon the sun at those times; the resulting radii from the intermediate pictures II to V present a tolerable accord, and, in order to render the first and last photographs in some measure available for the purpose intended, that is, for the determination of the scale-value of the micrometer, I have taken the sum of the photographic radii of sun and moon from II to V, or $33^t.131$, and supposed this value to hold good also for I and VI, which gives—

$$R_{I}=16^t.875 \text{ and } R_{VI}=16^t.890$$

consequently $\Delta_{I}=24^t.153$ and $\Delta_{V}=23^t.207$. The probable error of R, as found from any single photograph (inclusive of I and VI) equals about $\pm 3''.5$.

Should the sun's actinic power be different near the center and near the limb, a systematic deformation would result in the moon's photographic outline, especially for cases I and VI; but, as the curvature must be affected with the same sign, and the measured R have a different sign of deviation in our pictures I and VI, they throw no light on this subject.

Applying the known eccentricity, the measured distances of the centers of sun and moon for each of the photographs is deduced; and, comparing them with the true distances computed from the ephemeris, corrected by observations with eye and ear at Bristol, Springfield, and Des Moines, we find the following scale-values for one turn of the micrometer:

Photograph.	Springf. M. T.	Distance by photo.	☉ to ☾ center by corr'd eph.	Value of 1 turn of micrometer.
	h. m. s.	t.	"	"
I	4 21 54.52	24.174	1425.1	58.95
II	4 50 35.06	9.125	528.4	57.91
III	4 54 24.10	7.039	406.3	57.72
IV	5 19 38.42	7.221	418.9	58.02
V	5 22 47.78	9.025	524.2	58.09
VI	5 47 01.25	23.185	1348.0	58.14
Sum		79.769	4650.9	58.31

Giving the weight one-half to the measured distances for photographs I and VI, the value for one turn of the micrometer would equal $58''.20$. A closer agreement between the individual values for one turn of the screw would be desirable; the differences, however, are not much greater than what might be expected from the uncertainties in the resulting lunar radii, for the determinations of which we have, at best, less than half a circumference which can be submitted to measure. For the conversion of the measured distances into seconds, I prefer to use the value $57''.94$, deduced from II, III, IV, and V. The measured and computed distances of the centers of sun and moon then compare as follows:

	II.	III.	IV.	V.
	"	"	"	"
Distance of centers by protographic measures	528.7	407.8	418.4	522.9
Distance of centers by corrected ephemeris	528.4	406.3	418.9	524.2

The position-angle of the junction-line being known, we compute the difference in right ascension and in declination of the sun and moon, and find—

	"	"	"	"
Diff. in R. A., sun and moon, by phot	521.6	402.7	—413.1	—516.9
Diff. in R. A., sun and moon, by corr'd eph.	522.2	401.6	—413.9	—518.1
Diff. in decl'n, sun and moon, by phot	—169.6	—129.9	+132.8	+164.3
Diff. in decl'n, sun and moon, by corr'd eph	—167.0	—128.0	+132.4	+165.1

This would give an additional correction to the ephemeris of $-0''.6$ in diff. of R. A. (☾ — ☉), and of $+0''.8$ in diff. of decl'n (☾ — ☉), showing that the results from the photographic method do not sensibly differ from the results of the ordinary eye and ear method of observing, as practiced

at Springfield. The uncertainty of these apparent additional corrections amounts to nearly their whole amount. While the results by the two methods may have nearly equal value, the labor required by the photographic method is vastly greater, both in observing and computing.

By collating the results obtained from the Springfield and Shelbyville photographs of the eclipse, the latter gave an apparent correction to the moon's right ascension of $-4''.8$ nearly; the two values agreeing within their probable errors.

Respecting the application of photography to the next transit of Venus, I would beg leave to add a few remarks: In this case, where amount of labor is of no consequence, provided we obtain accurate results, we have the advantage of a complete circumference for perfecting the centering of the photograph, besides we may center on the sun as well as on the planet. The perpendicularity of the face of the plate to the optical axis of the object-lens must be mechanically insured. A sharp outline can certainly be secured, since an examination of micro-photographs showed no sign of granulation with a magnifying-power of about 50. Respecting unequal contraction of the collodion film, or distortion of the image, a glass plate, on which have been ruled parallel, equidistant lines, crossed by a second system of similar lines at right angles to the first, may be placed in the focus of the telescope, and may be there adjusted to indicate on the photograph the direction of a vertical or of a declination circle, as the case may be; distortion of the collodion film,* if any, will be apparent in the photographed lines, and can be allowed for. In the arrangement of the horizontal tube, as proposed by Professor Winlock, a fine plummet (silver thread) may be suspended in front of the collodion plate as near to it as can safely be done; its shadow will then be photographed together with the sun, and thus indicate the direction of the vertical; if two such plummets, or a glass plate (set by spirit-level) with ruled lines, be employed, the means will be given for obtaining a value of the micrometer-screw independent of the diameter of the photographed sun, which latter could not be trusted for this purpose. These remarks are only offered as suggestions in preparing for the work.

ADDITION TO PRECEDING REPORT.

In conformity with your note of the 10th of July, I have examined into the possible effect of the wearing of Rutherfurd's micrometer-screw on the measures of the eclipse-photographs.

The temperature and light being favorable yesterday, I measured the distances of the four lines of the test-plate, using a magnifying-power of 160, first over a part of the screw (reading 86 to 96) which had served for more than a thousand measures, next over parts of the screw which had been comparatively little used (readings 68 to 78 and 104 to 114). In each case twenty measures of ten turns were taken; the distance of the test-lines 1 to 2 and 3 to 4 are $\frac{1}{96}$ of an inch (or half a turn nearly); of 1 to 3 and 2 to 4, $\frac{10}{48}$ of an inch (or ten turns nearly). A unit in the last place (3d) of decimals recorded is $\frac{1}{48000}$ of an inch very nearly.

I append a specimen of part of the record:

Temperature, 85°. *Motion, forward.*

Test lines 4	3	2	1
104.341	104.843	114.342	114.844
2	2	3	3
2	3	2	4
2	2	2	5
2	3	3	3

* The substitution of the daguerreotype process was first thought of, but an examination of a daguerreotype showed so large a granulation that its use cannot be recommended.

Motion, backward.

104.340	104.844	114.342	114.843
0	2	3	2
1	3	1	3
1	2	2	2
1	3	2	2

From the record, I deduce the following result:

At 85° Fahrenheit, measured distance of test-lines, in turns and decimals, of the upper screw.

Readings.	1 to 3.	2 to 4.	Mean.	
			t. t.	
68 to 78	10.0002	10.0011	10.0006 ± 0.0003	Part little used.
86 to 96	10.0005	9.9997	10.0001 2	Part much used.
104 to 114	10.0010	10.0004	10.0007 2	Part little used.
Mean	....	....	10.0005 ± 0.0001	

The effect of wear would probably show itself most in the probable error (the measures being half with motion forward and half with motion backward). The actual differences are sufficiently accounted for by the probable errors of measures and a possible irregularity in the screw, and do not seem, as yet, to indicate any injurious wear. Supposin an irregularity of 0t.0004 in ten turn s its effect on the measured radius of the photographed sun would be 0t.0006, which is equal to 0″.03, one turn being nearly 58″. This small quantity is of no consequence in the results reached. The measures of the photographs are nearly all comprised between the readings of the upper screw 91 and 101 (turns), and between these limits no possible defect could have crept into the results.

[C. A. S.]

Table of geographical positions determined by the Coast Survey and occupied for observations of the eclipse of the sun August 7, 1869.

	Latitude.	Longitude.	Approximate elevation.
	° ′ ″ ″	h. m. s. s.	Feet.
Bristol, Tennessee (E. S.)	36 35 49.10±0.2	5 28 44.90±0.28	1,760
Shelbyville, Kentucky (A. S.)	38 12 45.36±0.1	5 40 53.05	....
Shelbyville, Kentucky (E. S.)	38 12 44.62±0.1	5 40 53.04	....
Falmouth, Kentucky (A. S.)	38 40 37.39±0.1	†5 37 09.3	....
Oakland, Kentucky (E. S.)	37 02 29.80±0.1	†5 45 01.2	....
Springfield, Illinois (E. S.)	39 49 02.50±0.1	5 58 33.62±0.26	500
Springfield, Illinois (new State-house dome)	39 47 56.71	5 58 37.18	....
Mattoon, Illinois (A. S.)	39 29 10.20±0.2	5 53 32.50±0.26	....
Des Moines, Iowa (A. S.)	41 35 02.69±0.1	6 14 29.08±0.27	833
Des Moines, Iowa (E. S.)	41 35 04.81±0.1	6 14 29.04±0.25	....
Burlington, Iowa (A. S.)	40 48 22.04±0.2	6 04 25.66±0.26	....
Cedar Falls, Iowa (A. S.)	42 32 32.3 ±0.5	†6 09 46.8 ±0.30	....
Saint Louis, Missouri (A. S.)	38 38 03.2 ±0.2	6 00 48.98±0.26	....
Kohklux, Alaska (E. S.)	59 23 41.6 ±0.3	9 03 33.85	....

The longitude of the Naval Observatory (dome) is taken as 5h. 08m. 12s.06 ± 0s.23.

The letters E. S. and A. S. indicate "eclipse-station," and "astronomical station," from which the eclipse-station is to be derived geodetically. The longitudes are reckoned west of Greenwich.

† Approximate value.

APPENDIX No. 9.

REPORT ON THE RESULTS FROM THE OBSERVATIONS MADE AT THE MAGNETICAL OBSERVATORY, ON CAPITOL HILL, WASHINGTON, D. C., BETWEEN 1867 AND 1869, BY CHARLES A. SCHOTT, ASSISTANT.

JUNE 29, 1869.

The observations which form the subject of this report were undertaken with a view of keeping up a continuity of record of the values of the magnetic declination, dip, and intensity in this city, and principally for the better determination of the secular change. A small wooden observatory, 8 feet by 5, was erected in the garden adjoining the brick house at the corner of Second street east and C street south, on Capitol Hill, 14″.4 south and 21″.1 east of the center of the dome of the Capitol, or in latitude 38° 53′ 06″.0, and in longitude 77° 00′ 14″.6 west of Greenwich. The space being limited, subsequent additions made to adjoining buildings were found slightly to affect the declination, on which account the present system of monthly observation was terminated, after completing a series extending over two and a half years. The observations were made by myself, except in January, February, and March, 1867, when Assistant E. Goodfellow attended to them under my direction. In the computations I was assisted by Mr. E. H. Courtenay. The regular days were the 14th, 15th, and 16th of each month (if a Sunday interfered the following day was included).

Magnetic instruments.—The declination and horizontal intensity were determined with magnetometer No. 7, previously used at Eastport and Portland, Maine. The box containing the small collimator-magnet is mounted over a 6-inch horizontal circle, and the reading-telescope moves eccentrically. The magnets, during deflections, remain, according to Dr. Lamont's method, at right angles to each other. The declination-magnet is 3.6 inches long; the smaller magnet, suspended during deflections, is 3.0 inches long; their diameter is 0.3 inch, and the weight sufficiently light to be suspended by a single fiber of untwisted raw silk. The astronomical azimuth was determined with a 5-inch theodolite from observations of Polaris and the sun, as follows:

	° ′
By observations of the sun, first and second limb, December 20, 1866, mark......	3 02.5 W. of N.
By observations of Polaris, telescope D. & R., January 4, 1867, mark............	02.3
By observations of Polaris, telescope D. & R., January 6, 1867, mark............	02.0
By observations of Polaris, telescope D. & R., January 7, 1867, mark...........	02.2
By observations of Polaris, telescope D. & R., January 7, 1867, mark...........	02.9
	3 02.4 ± 0′.1

A lightning-rod, on a house some distance off to the northward and nearly in the magnetic meridian, was used as mark.

The intensity was determined by deflections and vibrations with regard to induction.

The dip was measured with circle No. 10, having two position-needles, the axles of which can be turned, and were used in three positions each month. The circle is supplied with reading-microscopes, and the pointing is made on a small perforation in the needle. The polarity of the needles was reversed after one-half of the observations was completed.

The instruments were mounted and dismounted each month, and but one was used at a time; all magnets and objects of iron, not in use, being deposited outside the observatory.

Scheme of observing.—The declinometer was mounted and carefully adjusted the day before each term; the line of detortion was determined, the mark pointed at, and the horizontal circle read; the scale was then read every quarter of an hour, from 7¼ a. m., in December, January, and February; from 6¾ a. m., in March and April; from 6¼ a. m., in May, June, July,

and August; and from 6¾ a. m., in September, October, and November, in order to include the morning eastern elongation. When this was fairly passed, or when the north end of the magnet had fully commenced its westerly motion, the declination-readings were discontinued, and not resumed till about a quarter of an hour after noon, when, after a new determination of the line of detortion, the westerly elongation was observed, and the observations were concluded after the easterly motion had fairly set in. The mark was read again. The axis of magnet A was determined each month. After the completion of the observations of the morning declination, the magnet was vibrated, and the time of 100 vibrations noted several times with the motion of the magnet from right to left, and again from left to right; deflections were next made, with the above magnet in the usual positions, relative to the center of the instrument. The deflection co-efficient P was carefully determined, as well as the induction and the temperature co-efficient. Time was noted by mean-time chronometer Dent 2171, rated by means of the time-ball at the United States Naval Observatory.

The dip was next measured, on the first day with needles in position I, on the second day in position II, and on the third day in position III. The polarity was reversed in the middle of each set each day. The usual positions of face of needles and face of circle were attended to. The upper and lower ends of the needle were read, one after pointing with the upper microscope on the vernier to the right, and the other after pointing with the lower microscope on the second vernier After reversing the circle, the upper microscope was moved through twice the nadir distance of the complement of the dip. The bearings and the centering of the axles of the needles and the level of the instrument were attended to.

These observations being concluded, those of declination were resumed, and the day's work brought to a close, generally between 2 and 3 o'clock p. m.

Instrumental constants.—(*a.*) Value of a division of scale of magnet A. By first set, 2′.416; by second, 2′.479; by third, 2′.444; mean adopted, 2′.44. A small table of equivalents of scale-divisions was formed.

(*b.*) Moment of inertia of ring, magnet, and stirrup. Weight of ring, 509.79 grains; outer diameter, 2.000 inches; inner diameter, 1.598 inches, at 62° Fahrenheit. Co-efficient of expansion of bronze, 0.000010 nearly. The value of log K′ for various temperatures was tabulated. The moment of inertia of the magnet, &c., was determined by means of vibrations, without and with the ring, as follows: 7 sets of vibrations, in April, gave K = 2.3368 at 68°.7 Fahrenheit; 6 sets in July, 2.3365 at 82°.6; 11 sets in December, 1867, 2.3359 at 33°.1; and 12 sets in April, 1868, 2.3381 at 78°.8. Multiplying the weighted mean by π^2 we find $\pi^2 K = 23.064 \; (1 + 0.0000136 \; [t - 62°]) \pm 0.012$. This probable error produces a corresponding uncertainty in the value of the horizontal force x of $\pm$ 0.0012, and, in the value of the magnetic moment m of magnet A, of $\pm$ 0.0001, or nearly its $\frac{1}{4000}$ part. The values of log π^2K for various temperatures, between 32° and 92°, were tabulated.

(*c.*) Determination of the induction co-efficient. Since this co-efficient was determined and used here for the first time on the Survey, it was thought desirable to give the formulæ and computation in a complete form.*

Let h = induction co-efficient,
φ = angle of deflection for north end down (magnet up and down),
φ' = angle of deflection for north end up (magnet up and down),
i = dip, in our case, 71° 05′ nearly,
X = horizontal force, in English units = 4.32 nearly in our case;

then—

$$h = \frac{\tan \frac{1}{2} (\varphi - \varphi')}{X \tan i \tan \frac{1}{2} (\varphi + \varphi')}$$

A simple mechanical contrivance was devised to hold the magnet A in its various (vertical) positions in the *magnetic prime vertical* and at a convenient distance from the line of suspension of

* For the original investigations see Lamont's Handbuch des Erdmagnetismus, Berlin, 1849, p. 152, also the Admiralty's Manual of Scientific Enquiry, 3d edition, 1859.

the short magnet. From six sets of experiments on the 18th and 30th of July, 1867, the following results were obtained:

$$
\begin{array}{rl}
h = & 0.00031 \\
& 40 \\
& 40 \\
& 44 \\
& 44 \\
& 53 \\
\hline
\text{Adopted value} \ldots\ldots & 0.00042 \pm 0.00002
\end{array}
$$

I have also determined this co-efficient for the small (new) magnet marked .•. of magnetometer No. 8, viz: $h = 0.0014$, and for the large (old) magnet C_{32} of declinometer No. 1; from 4 sets, $h = 0.00075 \pm 0.00006$.

Let μ = increase in the magnetic moment m of the magnet, produced by the inducing action of a magnetic force equal to unity of the English measures, then $\mu = h\,m$; in our case $m = 0.396$ nearly, hence $\mu = 0.00017$.

To apply the correction for induction, we have to substitute in the value of T^2, as resulting from the vibrations, the quantity—

$$T^2\left(1 + \mu\frac{X}{m}\right), \text{ or } T^2(1 + h\,X)$$

In our case $\log(1 + h\,X) = 0.00079$, which is to be added to $\log T^2$ to correct for induction.

In the deflections we must substitute for—

$\frac{m}{X}$ the value $\frac{m}{X}\left(1 + \frac{2\mu}{r^3}\right)$, which, in our case, is readily allowed for, viz:

$$
\begin{aligned}
\log\left(1 + \frac{2\mu}{r^3}\right) = {} & 0.00009 \text{ for } r = 1\tfrac{1}{6} \text{ feet.} \\
& 0.00004 \text{ for } r = 1\tfrac{1}{2} \text{ feet.} \\
& 0.00002 \text{ for } r = 1\tfrac{11}{12} \text{ feet.}
\end{aligned}
$$

These corrections are necessarily small, since the angle of the deflection is never very great. If we wish to correct the *angle* of deflection u_0 for effect of induction, we have.*—

$$\sin u = \frac{\sin u_0}{[1 - (t' - t)\,q]\ \left[1 - \frac{\Delta m}{m}\sin u\right]}$$

where $\frac{\Delta m}{m} = \mu\,\frac{X}{m} = h\,X$, with the same results as above.

d. Determination of value of deflection co-efficients P, Q ....

In each month of 1867 deflections were observed regularly at distances of 14 and 23 inches. Let A = value of $\frac{m}{X}$ at deflecting distance r, and A_1 the same at r_1, each value having been *corrected for induction* and reduced to the *same* temperature, then—

$$P = \frac{A - A_1}{\frac{A}{r^2} - \frac{A_1}{r_1^2}}$$

To refer the first set to the temperature of the second, let t = temperature of second set, or standard temperature, t_1 that of the first, u_0 = observed angle of deflection of first set, and u_c its value corrected, or referred to temperature of second set; then—

$$\sin u_c = \frac{\sin u_0}{1 - (t_1 - t)q}, \text{ where } q = 0.00027$$

To simplify this correction for difference of temperature, we apply to the first value of $\log\frac{m}{X}$ (*i. e.*, for the short distance) the correction -0.00012 for each degree of difference of temperature.

* See Riddell's Supplement to Magnetical Instructions, (London, 1846,) p. 11.

This applies for a difference as great as 10°, without sensible error. Generally the temperature of the first set is lower than that of the second; the magnetic moment is consequently greater, as well as the angle of deflection. In this case u_c must, therefore, be less than u_o.

The following values were obtained for P:

January	− 0.0059	July	− 0.0066
February	− 0.0062	August	− 0.0026
March	− 0.0028	September	− 0.0060
April	− 0.0057	October	+ 0.0004
May	− 0.0071	November	− 0.0036
June	− 0.0026	December	− 0.0024

Hence P = − 0.0043 ± 0.0005.

To apply the correction for P, we have—

$$\frac{m}{X} = \tfrac{1}{2} r^3 \sin u \left(1 - \frac{P}{r^2}\right)$$

The value of $\log\left(1 - \frac{P}{r^2}\right)$ for the three distances employed is as follows:

For $1\frac{1}{6}$ feet...... 0.00136
$1\frac{1}{2}$ feet...... 0.00082
$1\frac{11}{12}$ feet...... 0.00050

The co-efficient of Q, involving the fourth power of r, may be omitted, since our ordinary deflecting distance ($1\frac{1}{2}$ feet) is greater than four times the length of the magnet.

e. Determination of the value of the temperature co-efficient q.

This co-efficient was determined by Mr. S. Walker, in September, 1861, in connection with the observations at Eastport, from deflections at temperatures varying between 33° and 85°.

For magnet A, q = 0.00026
25
30
26

Mean adopted............... 0.00027

f. The magnetic moment m of magnet A, as resulting for various temperatures from the operations of vibrating and deflecting may be referred to a standard temperature t_o by the formula

$$m_o = m\,[1 + (t - 62^\circ)\,q]$$

for which we can write

$$m_o = m + 0.00011\,(t - 62^\circ)$$

where m_o = magnetic moment of standard temperature t_o, assumed = 62° Fahrenheit.

g. To refer the resulting declination, on any day, as obtained by taking the *mean* value at the *eastern* and *western* elongations to the value resulting from *hourly* observations, the following tabular quantities were obtained from the Girard College observations:

Month.	f	Month.	f
January	−0.089	July	+0.005
February	−0.040	August	−0.023
March	−0.019	September	−0.044
April	−0.068	October	−0.096
May	−0.013	November	−0.096
June	+0.010	December	−0.154

Let r = diurnal range, then correction to the mean of declinations at east and west elongations $= fr$.

RESULTS.—The monthly results for magnetic declination, dip, and horizontal intensity are as follows:

Observed declination on Capitol Hill, Washington, D. C.

Month.	1867.	1868.	1869.	Annual change. 1868–1867.	Annual change. 1869–1868.
	° ′	° ′	° ′	′	′
January	2 46.5 W.	2 48.7 W.	*2 52.3 W.	+2.2	+3.6
February	47.9	49.0	*51.9	+1.1	+2.9
March	43.3	47.3	*53.7	+4.0	+6.4
April	46.4	51.4	†52.4	+5.0	+1.0
May	51.3	53.3	†54.1	+2.2	+0.8
June	49.6	53.1	†53.8 W.	+3.5	+0.7
July	46.4	50.8	....	+4.4	Present mean annual increase of declination = 2′.97.
August	47.7	*51.7	....	+4.0	
September	50.0	*52.7	....	+2.7	
October	49.5	*52.3	....	+2.8	
November	50.1	*52.2	....	+2.1	
December	48.2	*52.2	....	+4.0	
Mean	2 48.1 W.	2 51.2 W.			

* Corrected (by +11′.7) for local disturbance. † Corrected (by +2′.6) for local disturbance.

Month.	Time of eastern elongation. 1867.	1868.	1869.	Mean.	Time of western elongation. 1867.	1868.	1869.	Mean.
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
January	8 21 a. m.	8 44 a. m.	8 37 a. m.	8 34	1 08 p. m.	1 26 p. m.	1 34 p. m.	1 23
February	20	33	09	21	25	43	11	26
March	10	16	24	17	25	31	46	34
April	09	7 51	7 44	7 55	27	51	36	28
May	7 26	00	40	22	11	30	21	21
June	15	6 16	53 a. m.	48	17	09	11 p. m.	12
July	22	29	....	6 56	0 55	11	....	03
August	33	47	....	7 10	1 09	0 49	....	0 59
September	40	7 27	....	33	21	1 01	....	1 11
October	8 08	49	....	58	30	16	....	23
November	03	8 18	....	8 10	0 48	08	....	0 58
December	13 a. m.	10 a. m.	....	12	1 10 p. m.	15 p. m.	....	1 13

Turning epochs:

	h. m.		h. m.
April to September, inclusive, at	7 27 a. m.	October to March, inclusive, at	8 15 a. m.
April to September, inclusive, at	1 14 p. m.	October to March, inclusive, at	1 20 p. m.
On the average for the year	7 51 a. m.	and 1 h. 17 m. p. m.	

Month.	Diurnal range. 1867.	1868.	1869.	Mean.	
	′	′	′	′	
January	6.8	5.8	8.5	6.9	Results which agree well with those given for other stations in Coast Survey Report of 1865, Appendix No. 18.
February	6.1	6.5	9.9	7.5	
March	8.3	9.8	9.9	9.3	
April	12.3	9.5	11.6	11.1	
May	14.0	7.6	13.7	11.8	
June	10.2	11.4	10.2	10.6	
July	13.3	11.1	....	12.2	
August	14.6	15.4	....	15.0	
September	12.0	13.1	....	12.5	
October	10.3	10.6	....	10.4	
November	6.5	8.1	....	7.3	
December	5.2	8.0	....	6.6	
Mean	9.9	9.7	....	10.1	

It may also be noted that the magnetic axis of magnet A, since the commencement of the series, has gradually shifted in a direction toward its geometrical axis, as may be seen from the following results:

	Div.	Shift in minutes.
First six months of 1867, reading of axis	3.47	
		1′.16
Second six months of 1867, reading of axis	3.95	
		0′.44
First six months of 1868, reading of axis	4.13	
		0′.49
Second six months of 1868, reading of axis	4.33	
		Stationary.
First six months of 1869, reading of axis	4.25	

Observed dip on Capitol Hill, Washington, D. C.

Month.	1867.	1868.	1869.	Annual change. 1868–1867.	Annual change. 1869–1868.	
	° ′	° ′	° ′	′	′	
January	71 10.9	71 06.7	70 58.0	−4.2	−8.7	Present mean annual decrease in dip=4′.7.
February	09.5	05.3	58.2	−4.2	−7.1	
March	10.7	02.8	58.7	−7.9	−4.1	
April	11.1	05.9	57.3	−5.2	−8.6	
May	06.9	05.5	59.0	−1.4	−6.5	
June............	*04.6	04.7	56.0	+0.1	−8.7	
July	*05.5	06.5	....	+1.0	....	
August	*04.2	02.6	....	−1.6	....	
September	*08.6	01.3	....	−7.3	....	
October	06.2	02.1	....	−4.1	....	
November	03.7	70 59.1	....	−4.6	....	
December.......	70 58.7	57.7	....	−1.0	....	
Mean	71 06.7	71 03.4	....	−3.3	....	

* A spare needle of ordinary construction was used in the place of position-needle No. 1. In October a new axle was supplied to needle No. 1. Position-needle No. 3 was used unaltered throughout the series. The mean by the two needles is given in the above table.

This diminution of the dip is in accordance with the observations at Toronto, Canada, where the dip increased up to 1859, and has since been steadily decreasing. At Eastport, Maine, the dip was observed to be diminishing during the period 1860–'64; at Key West, Florida, the observations between 1860 and 1866 indicate a diminution. It appears from a former discussion * that the dip attained a minimum about 1842 on our Atlantic coast; from that time to about 1859, it was on the increase, when it unexpectedly reversed its motion and commenced again to diminish; possibly this increase during about seventeen years was only the effect of a secondary wave, masking for that time the general effect, which was decreasing the dip.

Observed horizontal force on Capitol Hill, Washington, D. C.

[Values expressed in English units.]

Month.	1867.	1868.	1869.	Annual increase. 1868–1867.	Annual increase. 1869–1868.	
January	4.312	4.323	4.349	+0.011	+0.026	Present annual increase in horizontal force 0.016, which is equal to 0.0037 of the force.
February	17	36	50	19	14	
March	20	28	49	08	21	
April	29	19	46	−0.010	27	
May	19	24	40	+0.005	16	
June............	22	26	50	04	24	
July	24	25	....	01	....	
August	17	48	....	31	....	
September	17	38	....	21	....	
October	19	46	....	27	....	
November	22	49	....	27	....	
December.......	29	50	....	21	....	
Mean	4.321	4.334	....	....	....	

* Coast Survey Report of 1856, Appendix No. 32.

The magnetic moment (reduced to temperature 62°) of magnet A during the above period resulted as follows:

Month.	1867.	1868.	1869.	
January	0.3932	0.3903	0.3833	Present annual loss of magnetism 0.0068, quite a small amount, showing the magnet to be approximating to the stationary condition.
February	32	0.3906	30	
March	26	0.3899	14	
April	35	0.3903	03	
May	25	0.3899	03	
June	22	54	02	
July	25	33	....	
August	21	31	....	
September	23	32	....	
October	17	31	....	
November	20	29	....	
December	17	31	....	
Mean	0.3925	0.3863	....	

The horizontal force previous to 1860 has been shown to have been on the decrease;* at Eastport, Maine, however, the horizontal force was found to be increasing since the commencement of 1862,† the reversal having first been noticed at Toronto, in 1860, by Professor Kingston, director of the observatory. It would seem that this increase is, perhaps, not yet general along our Atlantic coast, since the observations at Key West, as late as 1866, had not shown any increase, though it may have commenced in that year.

We have the total force as follows:

1867.5......13.35
1868.5......13.35
1869.3......13.33

I conclude this report with a collection of results of all magnetic observations for declination, dip, and intensity, in the District of Columbia, which have come under my notice.

Magnetic declination (D).

No.	Year.	D.	Observer.	Locality.	References and remarks.
		° ′			
1	1792.5	(−0 51.)	Ellicott	Inscribed on fourth stone from east corner of District of Columbia, northwesterly.	Reported by Mr. Mathiot; undoubtedly affected by local disturbances.
2	1792.5	−0 19.	......do	Inscribed on first stone from east corner of District of Columbia, northwesterly.	Reported by Mr. Wiessner.
3	1792.5	−0 10.	......do	Inscribed on east corner-stone of District of Columbia.	Do.
4	1809.0	+0 52.	King	Unknown	Coast Survey Report of 1855, p. 334.
5	1841.0	+1 20.2	Gilliss	Capitol Hill, north of Capitol	Do.
6	1842.0	+1 23.9	......do	......do	Do.
7	1855.5	+2 24.	Schott	......do	Do.
8	1856.6	+2 21.4	......do	Capitol Hill, Coast Survey Office	Coast Survey Report of 1856, p. 227.
9	1857.2	+2 24.8	Read	Near Capitol, south side	Coast Survey Report of 1858, p. 196.
10	1860.7	+2 26.7	Schott	Coast Survey Office	Coast Survey Report of 1860, p. 352.
11	1862.7	+2 39.4	......do	......do	Coast Survey Report of 1862, p. 212.
12	1863.6	+2 41.8	......do	......do	Coast Survey Report of 1863, p. 204.
13	1866.8	+2 44.2	Harkness	United States Naval Observatory grounds.	Manuscript.
14	1867.5	+2 48.1	Schott	Capitol Hill, Second street east and C street south.	Present report.
15	1868.5	+2 51.2	......do	......do	Do.
16	1869.3	+2 53.0	......do	......do	Do.

* Coast Survey Report of 1861, Appendix No. 22.
† Coast Survey Report of 1865, Appendix No. 18.

Magnetic dip (I).

No.	Year.	I.	Observer.	Locality.	References and remarks.
		° ′			
1	1839.2	71 17.5	Wilkes and Loomis	Yard in front of Capitol	Coast Survey Report of 1856, p. 242.
2	1841.0	18.3	Gilliss, Graham, Nicollet, Loomis.	Near Capitol, in garden east of it	Do.
3	1842.5	13.5	Graham, Lefroy	Public garden, east of Capitol	Do.
4	1844.4	16.4	Locke, Graham	Near Capitol	Do.
5	1845.3	[71 33.9]	Lee	Coast Survey Office, Capitol Hill	Coast Survey Report of 1856, p. 242; undoubtedly affected by local attractions or imperfect needle.
6	1851.5	18.9	Dean	Georgetown Heights	Coast Survey Report of 1856, p. 242.
7	1852.4	23.1	Hilgard	Between Capitol and city hall	Do.
8	1853.4	21.4	Gilliss	Near White House	United States Naval Astronomical Expedition to Chili, vol. vi.
9	1855.7	28.3	Schott	Smithsonian grounds and Georgetown Heights.	Coast Survey Report of 1856, p. 242.
10	1856.6	20.6	......do	Coast Survey Office, Capitol Hill	Coast Survey Report of 1858, p. 196.
11	1857.2	22.5	Read	Near Capitol, south side	Do.
12	1858.4	22.6	Schott	Coast Survey Office	Do.
13	1859.5	24.4	......do	......do	Coast Survey Report of 1859, p. 296.
14	1860.6	15.9	......do	......do	Coast Survey Report of 1860, p. 352.
15	1861.6	18.3	Walker	......do	Magnetic survey in connection with observations at Key West.
16	1862.6	18.0	Schott	......do	Coast Survey Report of 1862, p. 212.
17	1863.5	14.3	......do	......do	Coast Survey Report of 1863, p. 204.
18	1865.5	11.7	......do	......do	Manuscript.
19	1866.8	[72 02.0]	Harkness	United States Naval Observatory grounds.	Manuscript, undoubtedly affected by imperfect needle and perhaps local disturbance.
20	1867.5	71 06.7	Schott	Capitol Hill, corner of Second street east and C street south.	Present report.
21	1868.5	03.4	......do	......do	Do.
22	1869.3	70 57.9	......do	......do	Do.

Magnetic horizontal force (H) in English units.

No.	Year.	H.	Observer.	Locality.	References and remarks.
1	1842.5	4.347	Lefroy	Capitol grounds	Coast Survey Report of 1861, p. 247.
*2	1844.5	[4.282]	Locke	Georgetown	Do.
3	1844.5	4.313	......do	Capitol grounds	Do.
4	1844.5	4.282	......do	Magnetic observatory, Capitol Hill, north of Capitol.	Do.
5	1845.2	4.240	Lee	Coast Survey Office, south of Capitol	Do.
6	1845.9	4.233	......do	......do	Do.
*7	1851.5	[4.229]	Dean	Georgetown Heights	Do.
8	1855.7	[4.338]	Schott	Smithsonian grounds	Coast Survey Report of 1861, p. 247; undoubtedly affected by local disturbances.
*9	1855.7	[4.250]	......do	Georgetown Heights	Coast Survey Report of 1861, p. 247.
10	1856.7	4.309	......do	Coast Survey Office	Do.
11	1856.7	4.308	......do	Capitol garden, east of Capitol	Do.
12	1858.3	4.255	......do	Coast Survey Office	In connection with Kane's Arctic Expedition.
13	1859.6	4.307	......do	......do	Coast Survey Report for 1861, p. 247.
14	1860.7	4.319	......do	......do	Do.
15	1862.5	4.296	......do	......do	In connection with Dr. Hayes's Arctic Expedition.
16	1862.6	4.288	......do	......do	Coast Survey Report of 1862, p. 212, corrected by +0.033.
17	1863.6	4.282	......do	......do	Coast Survey Report of 1863, p. 204.
18	1866.8	4.300	Harkness	United States Naval Observatory grounds.	Manuscript.
19	1867.5	4.321	Schott	Capitol Hill, corner of Second street east and C street south.	Present report.
20	1868.5	4.334	......do	......do	Do.
21	1869.3	4.347	......do	......do	Do.

Values Nos. 2, 7, 9, marked *, would better be omitted in the discussion; they refer to Georgetown and to a locality affected by local disturbance. The Smithsonian grounds, also, are known to have a strong local disturbance.

These results may readily be expressed in analytical form; but, owing to our ignorance of the cause or causes of the secular change, such expressions require continually to be remodeled, and it may be as well to wait for further accumulation of observations before undertaking a new discussion.

I remain, sir, yours, very respectfully,

CHAS. A. SCHOTT,
Assistant, United States Coast Survey.

Professor BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

APPENDIX No. 10.

REPORT UPON DEEP-SEA DREDGINGS IN THE GULF STREAM DURING THE THIRD CRUISE OF THE UNITED STATES STEAMER BIBB, ADDRESSED TO PROFESSOR BENJAMIN PEIRCE, SUPERINTENDENT UNITED STATES COAST SURVEY, BY LOUIS AGASSIZ.

The survey of the Gulf Stream, including soundings and dredgings in deep waters, had been going on for two years under your direction, when I was invited by you to join a third cruise. The surveying-party this year, as before, was accommodated on board the United States Coast Survey steamer Bibb, master commanding, Robert Platt, who had charge of the hydrographic survey, while Assistant L. F. Pourtales, who had hitherto superintended the dredging operations, still continued to direct the same work. The object of my own connection with the present cruise was to ascertain how far the last investigations covered the ground to be surveyed, and to what extent and in what direction further researches of the kind were desirable in the same region and likely to furnish important information. The work of Mr. Pourtales had been so eminently successful, the results obtained in this short time so unexpected and of such high scientific value, that little more than a repetition, or perhaps, in some respects, a modification, of his results could be expected from my participation in this year's operations. It is a pleasure for me to state that our cruise—extending farther to the east in the Gulf Stream, between Cuba and the Bahamas on one side and Florida on the other, than those of previous years—confirmed in every feature the conclusions already reached by Mr. Pourtales. His results may, therefore, be considered as settled facts, deserving the fullest confidence of the scientific world, and requiring only, in order to obtain the appreciation they deserve, that kind of publicity which illustrated descriptions and maps can give them. When thus made known, it will be seen that we owe to the Coast Survey the first broad and comprehensive basis for an exploration of the sea-bottom on a large scale, opening a new era in zoological and geological research. I speak thus emphatically, because the data hitherto obtained concerning the animals of the deep sea have been rather isolated, and not methodically connected with one another and with a study of the inhabitants of shallower waters and the immediate sea-shore; nor have the previous collections been made over extensive areas and so combined that every newly surveyed point was determined with reference to earlier investigations, as was the case with the dredgings of the last two years. In your recent surveys of the Gulf, the dredging operations have been pursued over an area so large as to preclude the possibility of any accidental and ill-considered conclusions. I should not speak in such terms of investigations in which I have had a share had not the main results been secured by Mr. Pourtales before I joined the cruise.

There can be no doubt now that the area occupied by the reef which rises to the surface of the ocean has a peculiar, independent fauna, totally distinct from that of deeper waters. To this area belong those species of corals known as the true builders of coral reefs, and to which, in a previous report to your predecessor, I gave, on that account, the name of reef-builders. The range of this fauna in depth is very limited; it does not extend below ten fathoms, and is mainly occupied by corals acquiring in their aggregate communities very large dimensions, such as *Madrepora palmata*, *cervicornis*, and *prolifera*, *Porites astræoides*, *Oculina diffusa*, *Eusmilia fastigiata*, *Astræa annularis* and *cavernosa*, *Isophyllia dipsacea*, *Manicina areolata*, *Colpophyllia gyrosa*, *Mæandrina mammosa*, and other species of the genus, *Diploria cerebriformis*, *Siderastræa radians* and *siderea*, *Agaricia agaricites*, *Mycedium elephantopus*, *Millepora alcicornis*, the coarser and larger kinds of *Gorgonia*, and a host of animals of all classes living in and upon the reef, among which *Rhipidigorgia flabellum*, *Diadema antillarum*, and *Strombus gigas* are the most conspicuous. From this region (the only one of the kind which has been carefully surveyed by naturalists) I formerly secured those large and beautiful collections of corals which now adorn the Museum of Comparative Zoology.

Beyond this area, the width of which varies along the coast of Florida from a few miles, in the neighborhood of Cape Florida, to twelve, fifteen, or twenty miles and more off Cape Sable, we find another zone, rather sterile, or at all events not marked by that richness of animal and vegetable life which characterizes the reef range. The bottom of this second zone is a muddy mass of dead and broken shells, broken corals, and coarse coral-sand; it is chiefly inhabited by worms, and such shells as by their nature seek soil of this character, with a few small species of living corals, some Halcyonarians, and a good many *Algæ*. From the nature of the bottom of this zone, especially at a depth of from twenty to forty fathoms, it is evident that a large number of dead mollusks and zoophytes are scattered over its surface by the agency of the currents and tides, after they have been broken up.

I do not now enumerate the particular animals and plants found in this and the other submarine regions herein described, because the work of identification is as yet very incomplete; moreover, some of the most common and characteristic species are as yet neither described nor named, and would, therefore, be necessarily omitted in any list of the characteristic species of the Gulf Stream fauna. Indeed, for the present, such a list could only be an enumeration of species with which naturalists have become acquainted from specimens cast ashore, and would give no idea of the actual living faunæ in their natural *habitat*. On that account it is particularly desirable that the scientific harvest of these surveys should speedily be made known, accompanied by the fullest illustrations.*

A third region or zone, beginning at a depth of about fifty or sixty fathoms, and extending to a depth of from two hundred to two hundred and fifty fathoms, constitutes a broad slanting table-land, beyond which the sea-bottom sinks abruptly into deeper waters. The floor of this zone is rocky; it is, in fact, a limestone conglomerate, a kind of lumachelle, composed entirely of the solid remains of organized beings, a true concretionary limestone, such as we might find in several levels of the Jurassic formation, and more especially in that horizon which geologists call "Coral Rag." We have here a plateau extending for more than a hundred miles, beginning off the Marquesas and stretching to Cape Florida, corresponding to Coral Rag. It varies from eight to ten, twelve, or twenty miles in width—the greatest spread facing Sombrero—and is built up entirely of animals now living upon its surface, and constantly increasing the thickness of the bed by their accumulation. Large fragments of this rock were brought up by the dredge; so that its structure and characteristic remains of animals could be studied at leisure. I do not know that there is on record in the annals of our science a more direct illustration of the manner in which mountain masses of calcareous deposits have been accumulated on the bottom of the ocean. The animals inhabiting this plateau are innumerable, and as varied as those found along the shores most fertile in animal productions. A great variety of corals occur there, all of small size, and, strange to say, belonging to genera never known before from our sea-shores. Their aggregate affinity is, indeed, not with the living corals, but rather with the types of the tertiary and cretaceous periods. Echinoderms are equally numerous; they are also small as compared to those found nearer shore, and likewise recall, by their zoological affinities, the types characteristic of the cretaceous period. Salenoid and Discoidea-like forms, never known among living Echinoderms before, have been discovered on this plateau. Among mollusks I may mention one species—the *Voluta Junonia*, hitherto considered the rarest shell from the southern coasts of the United States, and known only from a very few worn specimens. Of that species, which is particularly interesting on account of its close affinity with *Voluta Lamberti* of the Crag, and with *Voluta mutabilis* of the Miocene beds of Virginia and Maryland, quite a number of living specimens, young and old, have been brought up by the dredge. Two species of Brachiopods—*Terebratula cubensis*, Pourt., and *Waldheimia floridana*, Pourt., are extremely common, and contribute greatly to give this fauna an antique character. Most of the other mollusks have not yet been identified. Worms and crustacea abound also, and a few fishes unknown to me have also been obtained. All these are still undetermined.

* The corals found in the two earlier cruises are described by M. Pourtales, in Nos. 6 and 7 of the Bulletin, pp. 103–141. A preliminary report on the Echinoderms is printed in No. 9 of the Bulletin, pp. 253–361. As I have not enumerated the species therein described, it may not be out of place here to remark that, though I have made some additions since, this report was prepared before Nos. 9, 10, 11, and 12 of the Bulletin had been handed in. The remarks upon the growth of corals were written immediately after my return from Florida, in May last.

The extraordinary richness, profusion, and variety of animal life displayed upon this table-land amazed me, not only on account of the peculiarity of the types, but from the vast number of individuals found together. The dredge coming up from such a depth, laden and crowded with all sorts of living creatures, as if it had been dragged in shoaler waters, was indeed a rare and startling sight for a naturalist. Such a result is the more unexpected, on account of the current impression, fostered by Edward Forbes's and Captain McAndrew's extensive dredging operations in the Ægean Sea, that as we descend below the surface of the ocean animal life gradually and steadily diminishes, till in deep waters it entirely fades away. As we have already seen, this is not the case, and Captain McAndrew has himself lately helped to dispel the illusion. Nevertheless, it is true that a change is perceptible in the character and size of animals inhabiting respectively deeper and deeper waters, as compared with those of the shallow coast zone. It may very justly be said that we have in the sea something corresponding to the alpine and subalpine flora, when contrasting higher levels with the plains; only that our submarine deep-water flora, or, rather, fauna, consists mostly of creatures hitherto little known, or even entirely unknown.

It is a surprising fact that the variety of marine plants does not keep pace with the variety of animals; they make a poor show when compared with the many and diversified sea-weeds found in the littoral mud-flats and upon shoal rocky bottoms. The sponges, however, thrive in deep waters better than the ordinary algæ; but the large and valuable sponges now gathered in such quantity along the whole coast of Florida are found on the littoral shoals only. In deep water we find, with a variety of larger species, a great number of small species of the same type, and among them a diminutive *Hyalonema*.

Permit me a suggestion here. You have repeatedly commemorated the discovery, by officers of the Coast Survey, of some submarine ledge or ridge, or peculiar configuration of the sea-bottom, by associating their names with the field of their operations. It would be appropriate and just that this extensive coral plateau, the characteristic fauna of which M. Pourtales has so faithfully explored, should bear his name and be called the "Pourtales Plateau."

To the seaward of this coral table-land, the bottom sinks rapidly to a depth of four or five hundred fathoms, reaching even eight hundred fathoms and more, though our successive dredgings have hardly extended beyond seven hundred fathoms. Over the whole of this area, which properly constitutes the lower floor of the Gulf Stream, the sea-bottom presents a uniform accumulation of thick, adhesive mud,* in which animal life is much less profuse than upon the coral plateau. It cannot, however, be assumed that this diminution of life is owing to the depth and consequent pressure of the water, or to the absence of light, but rather to the nature of the soil; for we find in it many animals to which such a *habitat* is congenial—a variety of worms, for instance, and such shells as seek muddy bottoms. I have not the least doubt that a rocky foundation at eight hundred or even a thousand and more fathoms would yield a large harvest of animals; unquestionably fewer than are found in shallower waters, but yet as varied and as numerous comparatively as are the alpine plants on the very limits of perpetual snow, wherever, in various latitudes, that vegetation can be compared with the flora of lower levels. If we have not succeeded in finding such a fauna in the deepest waters of the Gulf Stream, I hold that the cause lies chiefly in the absence of rocky bottoms in the deepest parts of the basin through which the great current of our southern coast flows. The character of the mud in the channel of the Gulf Stream does not warrant the supposition that the mud deposits derived from the turbid waters of the Amazons and Orinoco have extended as far north as the Gulf of Mexico, even though the great equatorial current sweeps past the mouths of these rivers.

There is one subject of scientific research, the connection of which with deep-sea soundings cannot fail to lead to unexpected results. When attempting to explain the structure of the stratified rocks, and many other phenomena connected with the general appearance of the earth's surface, geologists have not hesitated to ascribe, in a general way, the facts under observation to the agency of water; but they have rarely entered into such specific details as would establish a causal

* When dried, this deep-sea mud, with its innumerable and characteristic *Foraminifera*, remarkably resembles the chalk-marls of the cretaceous formation. The green-sand formation I have not investigated myself, but it has been minutely studied by Mr. Pourtales, who has ascertained that it is the result of a peculiar alteration, disintegration, and final aggregation of *Foraminifera*.

connection between all these facts, and the cause appealed to. In proportion as the sea-bottom becomes more extensively known, and the character of the materials lying beneath the water and their mode of arrangement are ascertained with greater precision, more accurate comparisons, in consequence of which current views may have to undergo considerable modifications, will certainly be made between geological formations of past ages, including all their deposits of various kinds, and the materials at present scattered in special ways over the ocean floor.

From what I have seen of the deep-sea bottom, I am already led to infer that among the rocks forming the bulk of the stratified crust of our globe, from the oldest to the youngest formation, there are probably none which have been formed in very deep waters. If this be so, we shall have to admit that the areas now respectively occupied by our continents, as circumscribed by the two hundred fathom curve or thereabout, and the oceans, at greater depth, have from the beginning retained their relative outline and position; the continents having at all times been areas of gradual upheaval with comparatively slight oscillations of rise and subsidence, and the oceans at all times areas of gradual depression with equally slight oscillations. Now that the geological constitution of our continent is satisfactorily known over the greatest part of its extent, it seems to me to afford the strongest evidence that this has been the case; while there is no support whatever for the assumption that any part of it has sunk again to any very great depth after its rise above the surface of the ocean. The fact that upon the American continent, east of the Rocky Mountains, the geological formations crop out, in their regular succession, from the oldest azoic and primordial deposits to the cretaceous formation, without the slightest indication of a great subsequent subsidence, seems to me the most complete and direct demonstration of my proposition. Of the western part of the continent, I am not prepared to speak with the same confidence. Moreover, the position of the cretaceous and tertiary formations, along the low grounds east of the Alleghany range, is another indication of the permanence of the ocean trough, on the margin of which these more recent beds have been formed. I am well aware that in a comparatively recent period portions of Canada and the United States, which now stand six or seven hundred feet above the level of the sea, have been under water; but this has not changed the configuration of the continent, if we admit that the latter is in reality circumscribed by the two hundred fathom curve of depth.

Geologists have appealed very freely to oceanic currents as accounting for the presence of loose materials upon the surface of the earth. But now that the actual mode of distribution of such loose materials, under the action of extensive and powerful currents, begins to be known, those who explain the facts in this way are bound to show that their arrangement actually agrees with the effects of oceanic currents. I must confess that I have looked in vain, in the trough of the Gulf Stream, for traces of the characteristic mud which pours from the mouth of the Amazons in quantities sufficient to discolor the waters of the ocean for a great distance from shore; and yet the equatorial current of the Atlantic is one of the greatest and most powerful of all known currents.

Another side of this subject is also immediately connected with deep-sea soundings. Geologists, and especially those of the school of Lyell, have again and again assumed the slow rising of extensive tracts of land from beneath the water, and taken all sorts of loose materials irregularly scattered over the surface of the land as evidence of its former submersion. But since the dredge has been applied to the exploration of the deep, and a great variety of animals, in a profusion rivaling that of shoal waters, have been brought up, not only from the immediate vicinity of the land, but at various distances, in increasing depth, from one to two and even many hundred fathoms, no observer is justified in considering extensive deposits of loose materials as marine in which no trace of marine organic remains is found. The very mud and sand of the deep teem with innumerable microscopic, living beings, the solid parts of which are easily detected in the smallest samples of marine deposits, and may therefore afford a satisfactory test where larger animals or plants are wanting. Now, after surveying the whole width of our western prairies, without finding anywhere a sign of marine animals or plants, I cannot see that there is any evidence of their marine origin, or of the influence of oceanic currents in accumulating or distributing the loose materials scattered over those vast plains. On the other hand, I have ascertained that the foundation rock, upon which these materials rest, is everywhere polished, grooved, and scratched in the same characteristic manner as the well-known glaciated surfaces, wherever exposed. I have seen

such polished rocks in the valley of the River Platte, not far from Omaha, and am now satisfied that the whole extent of the country, between the Alleghanies and the Rocky Mountains, was one unbroken glacier bottom. The scratched pebbles found among the loose materials of the great prairies confirm this view. For similar reasons, I am satisfied that the valley of the Amazons has not been under the level of the ocean since the tertiary period.

The most perplexing feature disclosed to me by our deep-sea dredgings and by my observations of the sea-shores along the Gulf Stream, on the Florida and on the Cuba sides, is the irregularity of the stratification of the Spanish banks as compared with the deposits on the American side.

Taken as a whole, the trough of the Gulf Stream, between Cuba and Florida, as well as farther east and north, presents features in its configuration widely different from the relief of any equally extensive area of the dry surface of our continents. The floor of this basin is gradually and slowly shelving from the Florida coast to greater and greater depth, while on the Cuban side it is rapidly rising again. The slope is, indeed, so rapid on the Spanish shore that, at a distance of less than two miles from the abrupt shore bluffs, the depth of the trough is generally from 3,000 to 4,000 feet, and here and there reaches 5,000 feet at a slightly greater distance. We have thus here a slope as steep as that of the steepest mountain ranges of that height, and even steeper; and, what is most surprising, the great inclination of this floor is not the result of uplifted and slanting beds of rock, but unmistakably the effect of the abrading action of the great current upon older coral formations, judging from the aspect of the shore bluffs, and their evident continuity with the general slope from the water-edge down to the greatest depth reached with the plumb-line and the dredge. This difference in the inclination of the slopes on the American and on the Cuban sides of the basin obtains for more than one hundred miles—from the Tortugas to Cape Florida—with the peculiarity only that in the direction of Salt Key Bank there rises, on the Cuban side, a low ridge from the deeper part of the trough, trending nearly parallel with the coast. Another remarkable feature of the edge of the great Florida reef consists in its having a less abrupt slope to the seaward than is ascribed to all the coral reefs of the Pacific Ocean. Nevertheless, the seaward slope of the reef is really steeper than the shoreward slope; and this is, it appears, an essential element in the growth and rise of all the coral reefs.

But while the great coral reef of Florida presents this exceptional character, the Bahamas and the reefs to the northeast of Cuba exhibit very abrupt slopes, and a great depth is reached close to the shores of these banks; so that the Bahamas resemble the coral-reefs of the Pacific much more than the reefs of the coast of Florida.

The whole group of banks and keys embraced between Double-headed Shot Key, Salt Key, and Anguilla Key is a very instructive combination of the phenomena of building and destruction. The whole group is a flat bank covered by four or five and occasionally six fathoms of water, with fine sandy bottom, evidently corals reduced to oolithes of various sizes, from fine powder to coarse sand, mingled with broken shells, among which a few living specimens are occasionally found. The margin of the bank is encircled on several points by rocky ridges of the most diversified appearance, and at others edged by sand-dunes. A close examination and comparison of the different keys show that these different formations are in fact linked together, and represent various stages of the accumulation, consolidation, and cementation of the same materials. On the flat top of the bank the loose materials are pounded down to fine sand; in course of time this sand is thrown up upon the shoalest portions of the bank, and it is curious to notice that these shoalest parts are its very edge, along which corals have formed reefs which have become the basis of the dry banks. The foundation rock, as far as tide, wind, and wave may carry the coarser materials, consists of a conglomeration of coarser oolithes, rounded fragments of corals, or broken shells, and even larger pieces of a variety of corals and conchs, all the species being those now found living upon the bank, among which *Strombus gigas* is the most common; beside that, *Astrœa annularis*, *Siderastrœa siderea*, and *Mœandrina mammosa* prevail. The shells of Strombus are so common that they give great solidity and hardness to the rock. The stratification is somewhat irregular, the beds slanting toward the sea at an angle of about seven degrees. Upon this foundation rock immense masses of Strombus, dead shells, and corals have been thrown in banks, evidently the beginning of deposits similar to those already consolidated below; but there is this difference in their formation, namely, that while the foundation rock is slightly inclined, and never rises above

the level of high water, the accumulation of loose materials above water-level forms steeper banks, varying from fifteen to twenty and thirty degrees. In some localities broken shells prevail, in other, coarse and fine sand; and the ridges thus formed, evidently by the action of high waves, rise to about twelve and fifteen feet. This is evidently the foundation for the accumulation of finer sand driven by the wind over these ridges and forming high sand-dunes, held together by a variety of plants, among which a trailing vine, *(Batatas littoralis,)* various grasses and shrubs are the most conspicuous. These dunes rise to about twenty feet; on their lee-side and almost to their summit grows a little palmetto. The sand of the dunes is still loose, but here and there shows a tendency to incrustation at the surface. The slope of these dunes is rather steep, sometimes over thirty degrees, and steeper to the seaward than on the landward side.

In the interior of Salt Key there is a pool of intensely salt water, the tint of which is pinkish or flesh-colored, owing to the accumulation of a little Alga. When agitated by the wind, this pool is hedged all round by foam of the purest white, arising from the frothing of the viscous water. Along the edge the accumulation of this microscopic plant forms large cakes, not unlike decaying meat, and of a very offensive odor. The foundation rock of this key is exactly like what Gressly described as the "*facies corallien*" of the Jurassic formation; while the deposit in deep water, consisting chiefly of muddy lime particles, answers to his "*facies vaseux.*"

Double-headed Shot Key is a long, crescent-shaped ridge of rounded knolls, not unlike "*roches mountonnees,*" at intervals interrupted by breaks, so that the whole looks like a dismantled wall, broken down here and there to the water's edge. The whole ridge is composed of the finest oolithes, pretty regularly stratified, but here and there like torrential deposits; the stratification is more distinctly visible where the rocks have been weathered at the surface into those rugged and furrowed slopes familiarly known as "*karren*" in Switzerland. It is plain that we have here the same formation as on Salt Key, only older, with more thoroughly cemented materials. The uniformity of the minute oolithes leaves no doubt that the sand must have been blown up by the wind and accumulated in the form of high dunes before it became consolidated. The general aspect of Double-headed Shot Key is very different from that of Salt Key. The whole surface is barren—not a tree, hardly a shrub, and the scantiest creeping vegetation. The rock is very hard, ringing under the hammer, and reminds one of the bald summits of the Jura, such as Tête de Rang, near La Chaux-de-Fond. It is evident that what is beginning on Salt Key has here been not only completed, but is undergoing extensive disintegration in Double-headed Shot Key, both by the action of atmospheric agents over the surface and by the action of tides and winds against the base of the key.

Among these older oolithic deposits, forming the main range of Orange Key and of Double-headed Shot Key, we recognize formations of more recent date, occupying the cavities of ancient pot-holes, which have gradually been filled with materials identical with those of the older deposits. The pot-holes themselves show nothing very peculiar; there are many such upon these keys—some large ones many yards in diameter and others quite small—evidently formed by the wearing action of loose pieces of harder coral rocks thrown upon the key by great waves, and only occasionally set in motion by the waters dashing over the key during heavy storms. The pot-holes nearest the water-edge are the most recent, and are mostly clean excavations, either entirely empty or containing sand and limestone pebbles lying loose at the bottom of the holes. Some of these excavations are circular, others oblong, still others have the form of winding caves opening toward the sea or upon the surface of the key. Beyond the reach of ordinary tides and of the waves raised by moderate winds, the pot-holes are generally lined with coatings of solid, compact, and hard limestone, varying from a thin layer to a deposit of several inches in thickness, and following all the sinuosities of the cavities in which they are accumulating. It is plain from their structure that these coatings are a subaerial formation, increasing by the successive accumulation of limestone particles left upon the older rock by the evaporation of water thrown upon the key when the ocean is so violently agitated as to dash over the whole key. Frequently the hollow of these coated pot-holes is further filled with consolidated oolithes; or thin layers of minute oolithes alternate with a coat of compact limestone, throughout the excavation, which often has been filled again in this way up to the general level of the surrounding surface. Occasionally these regenerated surfaces are again hollowed out by the action of storms, and the result is a dismantled pot-hole, in which their structure and the mode of their filling are distinctly exhibited.

The stratification of the main mass of these keys is very peculiar. Though evidently the result of an accumulation of oolithes thrown up by high waves, the beds are pretty regular in themselves, but slant in every direction toward the sea, showing that they were deposited under the action of winds blowing at different times from every quarter. It is further noteworthy, that, while the thicker layers consist of oolithes readily distinguishable to the naked eye, there are at intervals thin layers of very hard, compact limestone, alternating with the oolithic strata, which have no doubt been formed in the same manner as the coating of the pot-holes.

As in their general aspect the coral formations of the Cuban side of the Gulf Stream differ from those of the American side, so do also the rocks of the latter differ from the rocks observed upon the banks of Salt Key, Double-headed Shot Key, and Orange Key. We find upon the Florida reefs, as well as between the innumerable keys stretching along the American coast, and upon the coral plateau sloping toward the main trough of the Gulf Stream, extensive beds of regularly stratified rocks of various kinds. I have already described the limestone conglomerate of the Pourtales plateau. Such a formation exists nowhere else within the range of the Gulf Stream, unless it should be hereafter ascertained that a similar deposit extends along the submarine border of our continent, edging the American wall of the deeper part of the Atlantic trough. But in the shoal waters intervening between the coast of the peninsula of Florida and the keys and reefs there exist various deposits of an entirely different structure, the accumulation and increase of which are constantly going on. The most extensive of these formations is a regularly stratified oolithic rock, the grains of which vary from imperceptible granules to larger and larger oolithes, approaching the dimensions of pisolithes, and cemented together by an amorphous mass of limestone mud. The oolithes themselves are formed in the manner first described by Leopold von Buch. Hard particles of the most heterogeneous materials, reduced to the smallest dimensions, and tossed to and fro in water charged with lime, are gradually coated with a thin film of limestone, and then another and another, until they sink to the bottom, to be further rolled up down the sloping shore-bottom until they become cemented with other similar grains, and form part of the growing limestone bed. Of course the finer oolithes are seen nearest the shore-line, and it is instructive to see at low tide the little ripples of successive larger oolithes left dry as the water subsides. Naturally these materials are frequently thrown up along the beaches in layers of varying thickness, and in course of time become cemented, and are transformed into solid rock, over which crusts of hard, compact limestone are in the end formed by the evaporation of calcareous water dashed upon the dry surfaces.

In very shallow waters, which are not powerfully affected by tidal movements, and upon the bottom of which no oolithes are forming, we find extensive beds of a dull amorphous limestone, formed of lime-mud, alternating with seams of a more compact, hard limestone, in which a few oolithes may occasionally be seen that were floated over the flats in which such formations are going on. These deposits resemble the marly limestone of the Oxford beds. Of course these different rocks may alternate with one another, as, owing to the increase of the whole formation, the conditions for the deposition of one kind of rock may be followed by those favoring another combination. Again, in consequence of the changes in the direction of the currents, or as the result of a heavy gale, considerable deposits which have been going on regularly for a long time may suddenly be worn away and destroyed, giving rise, in turn, to the formation of conglomerates made up of limestone fragments of various structure, united together into very peculiar conglomeratic pudding-stone, with angular materials. The compact limestones are frequently as hard as the hardest limestones of the secondary formation, have a conchoidal fracture like the most compact Muschelkalk of the Triasic period, and may ring under the hammer.

Most of the keys consist of broken corals thrown up by the waves, including fragments of shells, sea-urchins, and occasionally bones of sea-turtles and fishes. At the Dry Tortugas and at the Marquesas, however, some of the keys are entirely made up of the decomposed fragments of corallines cemented together. The crescent-shaped joints of a large species of Opuntia are most prominent among them.

Nowhere within the range of the Gulf Stream and its borders have I seen a rock which could be supposed to have been formed by the materials accumulating in the greater depth of its trough, such as I have described above, page 210. And no rock in the whole Jurassic formation could have

been formed out of the kind of materials which are found in the deeper parts ot the Atlantic basin, along the American shores; I therefore do not believe that any of the rocks of the Jura and the Suabian Alp have been depósited in very deep waters.

The extensive area occupied by the keys and reefs of Florida, including the sloping coral plateau of the American side of the Gulf Stream bottom, may fairly be compared to the Jurassic formation, as it stretches across Central Europe and farther east, in the direction of the Caucasus and Himalaya Mountains. Indeed, the Jurassic formation, as a whole, bears the same relation to the older deposits upon which it rests, as the modern American coral formation sustains to the older parts of the coast of our continent. During the geological middle ages, the Jurassic formation was the submarine margin of a growing continent, as the Pourtales plateau forms at present the southern margin of North America.

These facts have an immediate bearing upon the question of the origin of submarine basins as compared with the inequalities of the mainland. The configuration and relief of our continents, as far as they are not the result of later denudations, have been determined by uplifts and the gradual rise of the land above the level of the sea, and hence have arisen the fractured ridges of mountain ranges, with their upright crests; while the areas of the great oceanic basins are surfaces of depression or subsidence, upon which prominent inequalities would of necessity be wanting, from the very fact that the breaks, where any occurred, must be turned downward. If this view is correct, it naturally follows that the main outlines and circumscription of the continents and of the oceans must have been determined at the very beginning of the formation of inequalities upon the earth's surface, and remained essentially the same through all geological ages, varying only as to their relative height and depth, as well as to their respective extension.

Such considerations enable us now to raise the question of the age of the Gulf Stream.. Our present knowledge of the atmospheric and oceanic currents justifies the assumption that, owing to the rotation of the earth upon its axis, and taking for granted that the latter has never changed its poles, the great equatorial currents, fostered by the trade-winds, must flow in an east-westerly direction, and be fed by northerly and southerly polar currents slanting westward toward the equator. As long as the chain of the Andes did not intercept the Atlantic equatorial current, it must have been continuous with the great Pacific current; and, as stated by A. Agassiz, in another report, there is palæontological evidence that during the cretaceous period the through channel was still open. I may add that I have myself seen the evidence, along the base of the Rocky Mountains, and on the western borders of the Amazonian Valley, of the post-cretaceous elevation of the great mountain range which rises like a huge barrier on the western side of the North and South American Continents, dividing the Pacific water-shed from that which feeds the Atlantic. We are thus justified in assuming that, even during the cretaceous period, there existed a great North Atlantic current, flowing from the northeast in a southwest direction, and that the Gulf Stream has assumed its present course in the opposite direction since that period; that is, since the Rocky Mountains and Andes have joined hands across Central America. This result adds greatly to the interest excited by the cretaceous and tertiary character of some of the animals discovered by M. Pourtales in the deeper parts of the Gulf Stream. The true significance of this fact is, however, too foreign to this report to justify a discussion of its bearing upon the question of.the origin of the present faunæ.

It would be of the highest importance to ascertain, by actual observation, the whole extent of the range of the deep-sea fauna recently discovered in the Gulf Stream, between the coasts of Florida and Cuba. To secure this information, a great amount of dredging must be done from the eastern shores of the United States to the deepest waters of the Atlantic Ocean, all along the coast from Florida to our Northern States. Until such a comprehensive survey has been carried out, we can only combine, as well as we may, the scanty data on hand, in our attempt to form any idea of the northerly extension of the animals now known to exist in that part of the Gulf Stream flowing between Florida, Cuba, and the Bahamas. Happily the English and the Scandinavian naturalists have already collected a vast amount of information concerning the marine faunæ of the coasts of Norway and the British Islands, and the recent expeditions undertaken by the Swedish and by the English governments, with a view of exploring the greatest depths of the Atlantic Ocean, cannot fail to afford the most valuable means of comparison between the faunæ of the two sides of the

Atlantic in different latitudes. From the reports of the British Association for Advancement of Science, from the publications of Professor Sars, from the reports of Professors Carpenter, Thomson, and Jeffreys, and from the private communications received from Dr. Smitt and Mr. Ljungman, the naturalists of the Swedish man-of-war Josephine, which recently visited the harbor of Boston, we have been able to ascertain that some of the species of our deep-sea animals of Florida are found far to the north of the British Islands, on the western coast of Norway, and near the Azores, upon the newly discovered "Josephine Bank." Now all these stations lie in the course of the Gulf Stream, as it divides into a northern or Scandinavian and a southern or Lusitanic branch, after crossing obliquely the Atlantic Ocean from our own shores, in the direction of Ireland; and the question naturally arises, is not this wide distribution of the Florida deep-sea fauna to be directly ascribed to the agency of the Gulf Stream? It can hardly be otherwise, at least within certain limits. But at the same time we must not forget that, in a comparatively recent period, the main motion of the North Atlantic must have been in a north-southerly direction, and that to this day there is a great northern current of cold water sweeping past the eastern shores of the United States; while the southern branch of the Gulf Stream flows in a southerly direction, past the western shores of Southern Europe; so that we may expect a strange mixture of arctic and subtropical animals in the great unexplored depths of the Atlantic, between America and Europe. It is to be hoped that the zeal with which the exploration of the deep ocean has begun may not flag before the whole problem is solved.

One of the most important results of this year's cruise, though not exclusively derived from deep-sea soundings, deserves a special mention in this report.

Taught by former investigations, upon other classes of animals, that in their affinities and relative standing organized beings exhibit direct relations not only to the changes they undergo while growing, but also to their succession in past ages, and to their present distribution upon the surface of the earth, I lost no opportunity of ascertaining to what extent these relations may also be traceable among the corals. From their simpler organization, and the less prominent differences which distinguish their numerous representatives, it seemed hardly probable that facts could be ascertained plainly bearing upon these questions; and yet, the moment I proceeded with the investigation, I perceived that there was before me a vast field, thus far entirely unexplored, from the survey of which much valuable information could be secured.

A fortunate circumstance unexpectedly favored my researches. In consequence of injuries to a breakwater adjoining Fort Taylor, a large number of granite blocks, which had been three years under water, were hauled up on shore, and I found them covered with a great number of specimens of different species of corals, in various stages of growth. The surfaces of the granite were still so clean that it was possible to detect the smallest young corals upon them, and to trace so many stages between them and larger ones as to leave no doubt of their specific identity. I made, with the assistance of M. Pourtales, a large collection of these young corals, which I afterwards leisurely compared with one another and with adult stocks of the same species. The result of this comparison I may express in few words: Corals undergo a succession of changes peculiarly their own, and yet hardly less marked than the embryonic changes already known among many animals. If we combine into a series all the changes thus far observed among different families of corals, an unmistakable gradation appears among them, akin to the series which may be traced among other animals in their adult condition, when we take the complication of their structure as a standard of their arrangement. Combining the evidence obtained from adult coral stocks, and their young at various stages of growth, it becomes evident that the representatives of the class of polyps do not stand upon the same structural level with one another; but that there are higher and lower types among them, recognizable without the aid of embryological data, even though it was the study of the young which led me to the recognition of their relative standing. This is not the place for a discussion of the principles of classification of polyps. I will only state, what I trust I shall be able to prove hereafter, that the Actinians proper stand lowest; next to them the Madreporarians, and highest the Halcyonarians. And as the Madreporarians form the most prominent feature in the coral reefs, I may add that among them the Turbinolians stand lowest, the Fungians next, then the Astræans, and highest the Madreporians. Now it is a most interesting fact that the successive changes which any representative of these different groups exhibit during their

growth recall the characteristic features of the groups immediately below. For instance, young Astræans, before assuming their solid frame, are Actinia-like; their first coral frame is Turbinolia-like; and from that stage they pass into Fungia-like condition, before they assume their characteristic Astræan features.

I will only describe a few cases, in order to establish this correspondence of growth and relative standing of adults upon a firm scientific basis. Beside multiplying through eggs, *Actiniæ* increase also by budding, and this takes place by a spreading of their base of attachment, (abactinal area,) from the margin of which new individuals arise and finally detach themselves. Such a mode of enlargement or spreading of a simple individual, by a widening of its base of attachment, I have observed in many genera among Fungians, Astræans, Oculines, and Madrepores. If we take, for instance, a *Siderastræa*, which, by the way, is a Fungian, and not an Astræan, as is shown by the structure of its tentacles, as well as of its coral stock, we find that the large rounded masses formed by these corals are at first thin, spreading disks, which only increase in thickness at a later time. The genus *Mycedium*, which, even in its perfect condition, constitutes a thin, spreading blade, may be compared, making allowance for the generic differences, to a young spreading stock of *Siderastræa*. In Mycedium the mode of growth is very plain. A series of specimens collected by M. Pourtales shows the beginning of such a coral community to be a single individual, the margin of which gradually spreads; from this spreading edge are developed additional individuals in the trend of the radiating partitions of the parent individual, spreading in their turn, while they remain connected with one another and with the central individual; this process going on until the coral stock has assumed its ordinary dimensions. Let us now conceive that the individual polpys, united as a coral stock in *Mycedium*, should increase vertically, as well as spread and multiply horizontally, the process of elevation beginning in the center we should have a *Siderastræa*. It is worth noticing, further, that the original central individual, from which the Mycedium community arises, is a diminutive Fungia, up to the time when new individuals arise around its margin. I have before me such young Myvediums, which might be mistaken for small specimens of *Fungiæ*, such as have been figured by Stuchbury and Milne Edwards. We are therefore justified in considering the genus *Fungia* as an embryonic form of the type of Fungians, when we compare it to *Mycedium*, *Agaricia*, or *Siderastræa*; and the propriety of assigning to Fungia proper a lower position in a natural system than that belonging to the compound types of the family must be obvious to all. The genus *Zoopilus* is only a Mycedium in which the individuals of the community are more intimately blended together than in *Halomitra*, thus forming a transition to Fungia proper. I have had an opportunity of examining also the growth of *Agaricia*. With the exception of generic differences in its structure, it exhibits in its growth the same features as Mycedium. The very youngest Mycediums exhibit Turbinolian affinities, inasmuch as the interseptal chambers are open from top to bottom, and exhibit neither traverses nor synapticules.

Among Astræans the early growth of a community takes place in the same manner as among Fungians. Naturalists are accustomed to consider the formation of the hemispheric masses of these corals as arising from the formation of vertical buds around and between those which preceded. This mode of enlargement of the communities obtains really in later periods of their growth; but it is not in that way that the foundation of the community is laid. *Astræa annularis*, the most common species among the Madreporarians of Florida, exhibits the formation of these stocks very plainly. The vast number of young stocks of this species which I have collected in every stage of growth leaves no doubt upon the subject. A simple individual polyp spreads by the elongation of its radiating partition, Mycedium-like, in every direction, giving rise at appropriate distances to new centers or individuals around the first; and this goes on, without a marked vertical enlargement of the new individuals, until the community has acquired a diameter of several inches; just as in the cases of *Mycedium*, *Agaricia*, and *Siderastræa*. The appearance of this spreading margin of the young *Astræa* stock is so like that of a spreading Fungian that, if detached from the well-defined circular individuals occupying the center of the disk, it would unhesitatingly be taken for a fragment of a Fungian. It is only at a later time that in *Astræa annularis* the members of the community are developed in a vertical direction, and the community as a whole is enlarged by the interpolation of new individuals, to assume the form of a hemispheric mass. I have observed the same mode of growth in *Astræa cavernosa*, in *Manicinia*, in *Symphyllia*, in *Favia*, in *Colpophyllia* and

in *Mæandrina*. Of *Manicina*, I possess a series of young still exhibiting their Turbinolian characteristics, with interseptal chambers open from top to bottom, and without a trace of traverses. The corals with undulating and meandering trenches arise also, like compound Fungians and compound circular Astræans, from single individuals, with circular outlines spreading from the margin, after the fashion of Fungians, just as much as *Astræa* proper. The peculiarities exhibited by each type cannot well be described without figures; I shall therefore not attempt here a detailed report of all the facts I have observed, reserving a fuller statement for a special memoir. But *Mæandrina* exhibits some features so particularly interesting that I cannot pass on without giving some more special account of them. When the young spreading Mæandrina has acquired the dimensions of about half an inch, still plainly exhibiting Fungian characteristics, its marginal extension gives rise to the formation of isolated clusters of rising radiating partitions, which stand distinct from one another, just like the characteristic hills of a *Hydnophora;* in fact, the young Mæandrina passes from a Fungian into an Hydnophora state, and in its farther extension, which takes place when the community has about two inches in diameter, when the trenches and walls begin to curve, while the margin is still spreading horizontally, the young Mæandrina assumes the appearance of an *Aspidiscus*, a genus of the cretaceous period; in truth, it then resembles Aspidiscus and Hydnophora more than any adult representative of its own genus. We have here the highest complication of the Astræoid type, exhibiting successively Fungian characters, common *Astræa* characters, Hydnophora characters, and Aspidiscus peculiarities, before it assumes its own prominent and permanent features. The Turbinolian stage I have had no opportunity of observing in Mæandrina. This genus seems to grow more rapidly than other Astræans, and it was with difficulty I secured the earlier Astræan and Fungian stages of its growth.

Zoologists are so accustomed to consider the *Oculinidæ* and *Madreporaidæ* as branching corals, that they may be surprised at the announcement that these families, like the Astræans, have their spreading Fungian-like stage of growth; and yet I have before me a complete series of Oculina stocks, among which small clusters of individuals in simple juxtaposition exhibit the earlist condition thus far observed; others consist of flat, spreading disks, several inches in diameter, without a vertical branch; while in others the branches seem to rise as small knobs and then begin to assume the ramified forms under which the Oculinas are generally represented in our museums. Even our most branching Madrepores, such as *Madrepora prolifera* and *cervicornis*, form spreading disks before they rise into branching stocks. *Madrepora palmata* is, as it were, an overgrown embryonic condition of the ramified species.

This summary of the facts concerning the growth of our coral stocks can leave no doubt respecting the correspondence of the phases of growth of the polyps, and the gradation which may be recognized in full-grown communities of these animals. If we extend these comparisons to the representation of the class in earlier geological periods, down to the present time, we cannot fail to perceive that the series exhibiting their succession in time coincides also with that of their relative standing and that of their growth. In order to make this plain, it would be necessary to enter into a discussion upon the real affinities of corals, for which this is not the place. I would state, however, that the knowledge I have acquired of the Fungian affinities of *Siderastræa* leaves no doubt in my mind that a large number of corals, among the representatives of the oolithic series generally referred to the family of Astræans, are genuine Fungians; thus showing a preponderance of the Fungian type at a period anterior to that in which the Astræans became more numerous. That the genuine Madreporians are of still later date in geological history has long been known. I would state also that from an examination of the soft parts of several representatives of the family of *Eupsammidæ*, I have satisfied myself that they are not allied to the true Madrepores, as Milne Edwards and Haime supposed, but belong in the neighborhood of the Turbinolians. If we now remember that the Acalephian affinities of the *Tabulata* are unquestionable, and that, with them, the *Rugosa* must be removed from the class of Polyps and referred to that of the Acalephs; and if we further take into consideration the fact that *Palæodiscus* belongs to the type of Rugosa, and not to the family of Fungians, it becomes evident that in their order of succession from the Mesozoic era, in which they make their first appearance, the great types of the class of Polyps have succeeded one another in the following order: first Turbinolians, next Fungians, next Astræans, and last Madrepores; in exactly the sequence in which these types stand to one another, as far as their

structural gradation is concerned, and in exactly the same order in which, during their growth, these corals pass from one stage to another.

If we now turn our attention to the distribution of these animals in the ocean at different depths, it is equally unquestionable that the lowest types—Turbinolians and *Eupsammidæ*—range in the greatest depths, and form there the principal feature of the coral population. It is equally apparent, from the facts ascertained by the dredgings of M. Pourtales, that the various types of Astræans, including Stylaster, Oculina, and Parasmilia, appear next, the Stylasterians and Oculinians, as the lowest, ranging deepest, and that Astræa proper, Manicina, Meandrina, and Colpophyllia, with Porites, are already types of shallower waters, while the Madrepores are, of all the genuine corals, those which have the most limited bathymetric range. I have not yet sufficient data upon the relative standing of the different types of *Halcyonaria* to extend this comparison to that order of Polyps. The results enumerated above are, however, already sufficient to show that, in the relations animals exhibit among themselves and to the elements in which they live, there are other connections to be traced besides those arising from descent or the struggle for existence.

I have reasons for supposing that the investigation of the Gulf Stream, as presented in former reports of the Coast Survey, has not yet reached its easternmost boundary. It was natural that the earlier explorations should have stopped where the great current no longer exhibits its characteristic peculiarities, and that its eastern range should have been traced with less minuteness than its alternate streaks of warm and cold water nearer shore. But now that the influence of the Gulf Stream upon the geographical distribution of organized beings appears distinctly as one of its most characteristic, though least suspected features, it will be necessary to extend the survey farther out into the Atlantic Ocean.

For the present I would suggest the following lines for soundings and dredgings:

1st. One line from the Atlantic coast in Georgia or South Carolina to deep water, outside the range of the Gulf Stream, chiefly with a view of tracing the northern limits of the fauna of Florida.

2d. One line from the Atlantic coast in North Carolina or Virginia to the Bermudas and beyond; with the special view of connecting the deep-water fauna of the Gulf Stream with the shore fauna of these islands and that of our own coast, upon which Cape Hatteras marks the limits between two natural zoological littoral provinces.

3d. One line from Cape Cod or from the coast of Maine, in a southeast direction, across the Gulf Stream, with the special view of ascertaining the boundaries between the shore fauna and that of the Gulf Stream at this latitude. This line would afford the means of extensive comparisons with our Acadian fauna, which has already been carefully explored as far as Grand Manan, by Dr. Stimpson, Professor Verrill, and myself. Shorter lines from Sandy Hook to the trough of the Gulf Stream would add much value to the results obtained by dredgings from the coast of Massachusetts or Maine across the Gulf Stream.

I would also recommend one line across the Caribbean Sea, from Cumana or La Guayra to Porto Rico, and one outside of the Small Antilles from the mouth of the Orinoco to Antigua; with the special view of ascertaining the area over which the mud deposits of the Orinoco spread, and how far they affect the Caribbean Sea.

But the most important line beyond our immediate shores, connected with the past history of the Gulf Stream, would be one from Panama westward into the deepest waters of the Pacific; for dredgings in that direction may prove that the deep-sea fauna is identical on both sides of the Isthmus, and that therefore, at a comparatively recent epoch, the great equatorial current of the Atlantic extended without serious obstructions over parts of Central America to the Pacific Ocean.

CAMBRIDGE, *November* 16, 1869.

APPENDIX No. 11.

THE GULF STREAM.—CHARACTERISTICS OF THE ATLANTIC SEA-BOTTOM OFF THE COAST OF THE UNITED STATES, BY L. F. POURTALES, ASSISTANT UNITED STATES COAST SURVEY.

Within the past few years a great interest has been manifested in the exploration of the bottom of the sea at great depths, and a rich and important field of scientific inquiry has thus been opened. Previously, it is true, naturalists had engaged in dredging, but it was mostly in moderate depths, and not far from shore. The restricting reasons were partly the expense, too considerable for private undertakings, and partly the authority of a naturalist, who, although an acute observer, was misled by fortuitous circumstances to regard the abyssal region as unfit for animal life. It was only long after his death that the error was recognized. An opposite view has been confirmed by the discoveries of the Coast Survey, and by the soundings preparatory to laying the Atlantic submarine telegraph-cable. Then only it became apparent how important for science the thorough exploration of this new field of research would become.

Of European nations England, Norway, and Sweden have particularly distinguished themselves in this field. In the present year England and Sweden have sent out expeditions for deep-sea dredging, and it is known that important results will in due time be published.

It is fit, therefore, to review at the present time the share which the Coast Survey has taken in such investigations, and also to take a general view of the formation of the sea-bottom along the coast of the United States as developed in our researches.

When Professor Bache first entered on his duties as Superintendent in 1844, he directed the preservation of the specimens of bottom brought up by the lead in hydrographic surveys. The object was twofold: first, to make certain the character of the bottom as it is usually marked on the charts, and secondly, to collect specimens for scientific investigation, at that time probably the first collection of the kind.

The ordinary hydrographic surveys extend only to the hundred fathoms line, but during the explorations of the Gulf Stream, under the direction of Professor Bache, specimens were obtained from much greater depths and in considerable quantities. No off-shore explorations were prosecuted during the rebellion, but in the last three years a special exploration by means of the dredge has been continued in charge of Assistant Pourtales.

The results from the beginning will now be recapitulated briefly in their order.

At first specimens of bottom were obtained in the usual way of seamen, by arming the lead with tallow; but as the quantity of material brought up in this way was very small, and almost useless for microscopical observation, except after a tedious removal of the tallow by chemical agents, it became necessary to devise better means. Each of the Navy officers engaged in this special hydrography occupied himself for a time with such inventions, and used his favorite model. The most useful, perhaps, were the sounding-cups of Lieutenants Stellwagen and Sands. The first being simple, convenient, and cheap in construction, has probably been the most in use, particularly in shoaler waters. It consists of a small cast-iron conical cup, screwed on a rod projecting from the lower end of the lead. A loose leathern cover, kept down by the pressure of the water when the lead is hauled up, prevents the material from being washed out of the cup. In the invention of Lieutenant (now Commodore) Sands, a lateral opening into the conical projection of the lead is exposed by pressure against a spring when the cone penetrates the bottom, which spring again covers the opening when the lead is drawn out. Combined with the detaching-lead invented by the same officer, this contrivance has proved very useful in great depths. It has the advantage over the well-known Brooke's lead of bringing up larger quantities of material.

Collected by such means, the specimens are preserved in small bottles properly labeled with the indication of date, latitude, longitude, and depth. The number of specimens in the Coast Survey collection amounts now to about nine thousand.

The first microscopical examination of the specimens was made by the late Professor J. W. Bailey, of West Point, who first called attention to their richness in *Foraminifera*. Later, and particularly after Professor Bailey's death, the continuation of the investigation was intrusted to Mr. Pourtales, but as he could devote to it but part of his time, being engaged in other duties, the work is yet in progress. It is, however, possible, even now, to throw such a general glance over the constitution of the sea-bottom along a large portion of the Atlantic coast as will properly introduce the more special consideration of the results of the recent dredging explorations.

On the accompanying map the chief constituents of the sea-bottom are indicated by colors for the region comprised between Cape Cod and Cuba. To the north of Cape Cod the bottom differs considerably, and is broken by frequent masses of rock. The examination of it is not complete enough to be taken into consideration now. As shown by the map, two main divisions strike the eye immediately: they are the *silicious* and the *calcareous* bottom, the first prevailing near the coast as far south as Cape Florida; the calcerous, with two important subdivisions, in greater depths, and along the southern extremity of Florida, the Bahamas, and part of the coast of Cuba. It is remarkable at the first glance, how closely the limits of the silicious bottom coincide with the limits of the cold southerly current and the limits of the calcareous with the warm waters of the Gulf Stream. On the other hand, these limits coincide also at the north perhaps more closely with the hundred-fathoms curve. It appears more plausible to attribute the distribution of organic life to which the bottom owes its supply of lime to increase of depth, rather than to difference of temperature, the more so as there is no correspondence between the temperature at the bottom and at the surface of the water. We shall recur to this view presently.

A smaller field is occupied by muddy bottom off the eastern end of Long Island, and off Block Island to the southward of Martha's Vineyard and Nantucket. The mud or ooze had probably its origin in the tertiary formations, of which we see only the remnants in the cliffs of Gay Head and in a few localities of small extent on the coast of Massachusetts, as at Marshfield and elsewhere. Known to seamen under the name of the "Block Island soundings," this sea-bottom is, in thick weather, a very useful indication to them of the approach of land. A similar sea-bottom is found in the so-called "mud-holes" off the entrance to New York. They are depressions below the general depth of the surrounding bottom, filled with mud, and range in the direction of the entrance to the bay. Professor Dana considers them as traces of the ancient bed of the Hudson, at a former geological period, when this bottom stood above the bottom of the existing sea. The "mud-holes" are also important guides to navigation.

Silicious bottom.—We have chosen for a nearer elucidation of this formation the region in the neighborhood of New York, and off the coasts of Long Island and New Jersey, because abundant materials were collected at an early period, and examined by Professor Bailey and Assistant Pourtales. With few exceptions, the same order of arrangement prevails on other parts of the coast.

The bottom falls off very gradually to near the hundred-fathoms line, in the neighborhood of which the water deepens rapidly. The same slope to seaward is common, and may be seen, for example, on the fine chart of the sea-bottom near the coast of France, by Delesse. It is therefore with very good reason that the one hundred-fathoms line is indicated on the best geographical maps, for it marks the real contour of the continents.

The sand of the American coast is composed chiefly of a yellowish quartz, (in the Gulf of Mexico often pure white,) with more or less black specks of hornblende and a little felspar. The degree of coarseness is very variable, ranging from an almost impalpable grain to the size of peas or beans. These differences are probably due to the winnowing effect of currents, and in smaller depths to the waves. Among the coarser materials, rolled pebbles can occasionally (though not often) be recognized as belonging to some of the older sedimentary rocks, which appear nowhere along the coast in this vicinity, and fragments of which have probably been brought down the rivers by ice, from the localities on their upper courses where these rocks are found in place.

Off Long Branch and off Rockaway beach, near the entrance to New York Bay, the sand contains a large mixture of black grains. They are greensand-grains or glauconite, casts of the shells

of *Foraminifera* from the greensand formation of New Jersey, and have been washed out either from the shore or from an outcropping of the beds under the sea-level.

The examination of the organic constituents of the sea-bottom was, of necessity, a microscopical one, because of the manner in which the specimens were obtained. It is true that now and then small shells and Echinoderms, or fragments of larger ones, were brought up by the lead, but in the aggregate not enough to give indications of their distribution. It was principally to the *Foraminifera* that our attention has been given, because these beings are large enough to be recognized with the ordinary lens, and because, at the outset, the examination sought to point the navigator to characteristics, additional to those of color and quality, in his soundings.

In correspondence with the accompanying map, certain regions off the Atlantic coast are characterized by the prevalence of certain forms of *Foraminifera*. The first region, counting from the coast-line, is characterized by a great poverty of forms. Excepting a few very small *Polystomellæ*, we find nothing in the sand, which is here kept in continual motion by the waves. This region we may consider to extend to a depth of ten or twelve fathoms. Further seaward we find different species of *Miliolinæ*, but never in large numbers. We find them to about forty fathoms, and also beyond, as it were sporadically.

From twenty-five to seventy fathoms *Truncatulina advena d'Orb*, is the characteristic form, and occurs occasionally in considerable numbers. The next region of the larger *Marginulinæ* and *Cristellariæ* encroaches on the former from about thirty-five fathoms, and extends as far as one hundred fathoms and beyond.

From about sixty fathoms the sand begins to be mingled strongly with *Globigerinæ*, whose numbers increase so much with depth, that at one hundred fathoms they are about equal in number with the grains of sand, and in greater depths they become the chief constituents of the sea-bottom, and lead us to the calcareous formation, in the consideration of which we shall mention them again.

In the mud of the "Block Island soundings," and of the "mud-holes," we find of organic forms very little else than *Guttulinæ*, and those, even, are rather scarce.

The same distribution prevails all the way to Cape Florida, with few exceptions. Interruptions are rare in this great sandy plain. Thus we find only one or two small rocky patches in the neighborhood of the entrance to New York Bay. There are also, off the coasts of North and South Carolina, rocky banks of small extent, not much raised above the general level of the sea-bottom. These consist of a calcareous material, and are probably the continuation of the tertiary beds found in the land along those shores. They are inhabited by corals, (oculina,) gorgonians, and various other animals, and are much richer in fishes than the sandy bottom, whence they are generally called *fishing-banks* by the inhabitants. Several such are found off Cape Fear, and, to judge from the nature of the corals and shells thrown up on the beaches near Cape Hatteras and Cape Lookout, similar banks, but of small extent, probably exist in the vicinity.

The sandy bottom ends exactly at Cape Florida. Key Biscayne, of which the southern point is Cape Florida, consists in great part of silicious sand. The next island, to the southward, only five miles distant, shows no trace of sand, but consists exclusively of coral limestone, of which also is formed the whole range of the Florida Keys, with the exception of the Pine Keys, standing somewhat back from the range. These, according to Professor Agassiz, contain silicious sand, for which reason they are the only ones that support the growth of pine trees—whence their name.

About Cape Sable silicious sand re-appears, and extends along the western coast of Florida, though at first strongly mixed with lime.

It is remarkable how the littoral fauna changes with the constitution of the bottom. Many forms of animals peculiar to the Carolinian fauna disappear at Cape Florida and re-appear at Cape Sable and on the west coast of the peninsula. Between these points they are entirely crowded out by the interposition of the West Indian fauna of the coral reefs. To take but one example, oysters are not found on the coral bottom, though abundant to the east and west on the sandy bottom.

Calcareous bottom.—The calcareous bottom, indicated on the map by a blue tint, is, as is well known, entirely of organic origin. According to the classes of organized beings which have contributed the greatest part, we can subdivide this formation into coral and foraminiferous formations, which will be found distinguished on the map by lighter and darker tints.

Coral formation.—It is generally known that corals are developed so extensively as to contribute to the formation of the bottom or of the adjoining land, but only in tropical and sub-tropical regions. Their northernmost limit on the coast of the United States is, as we have stated, Cape Florida.

Of the littoral corals, and the reefs which they build upon the coast of Florida, it is not our object to treat in this paper. Professor Agassiz has fully discussed that subject, but his researches have not been fully published.

Outside of the reef, and in greater depths, this formation was little known, until, as before mentioned, a thorough examination of the bottom by means of the dredge was instituted. Assistant Henry Mitchell conducted the physical exploration of the Gulf Stream, and Assistant Pourtales the dredging operations. The Coast Survey steamer Bibb, in charge of Acting Master Platt, was designated for the service, and was supplied with the necessary apparatus, among which was the steam-reel, an almost indispensable help to bring up the deep-sea lead and the dredge from great depths without loss of time. The Museum of Comparative Zoology, in Cambridge, furnished the necessary means for preserving the collection.

In the year 1867 a beginning was made, in connection with the soundings preliminary to laying the telegraph-cable between Key West and Havana. In 1868 and 1869 the researches were continued, in the present year under the eye of Professor Agassiz, who spent a considerable part of the season on board of the steamer.

On the maps are indicated the lines of dredgings and the dredging-stations, without, however, indications of the depth, on account of the small scale. The sections given on the sketch in part supply that want.

The results are, in the main, the following: The coral reef proper is pretty sharply limited, because of the well-known fact that the large reef-building corals flourish only near the surface. Outside of it the slope is not very steep, and not to be compared in this respect with the abrupt precipices out of which rise the coral islands of the Pacific Ocean, or even the reefs of the Bahamas. From the reef down to a depth of about ninety or one hundred fathoms, the sea-bottom consists principally of dead shells, fragments of corals and similar materials, more or less broken or rolled. Of living animals or plants there are not a great many, among the corals only a few small species, (Balanophyllia, Madracis, Oculina.)

On leaving this first region we find a rocky plateau, with very moderate slope, beginning a little to the westward of Sand Key and extending to the northward and eastward until it reaches its greatest breadth, of about eighteen nautical miles, a little to the eastward of Sombrero. It then begins to diminish in breadth, and finally ends between Carysfort Reef and Cape Florida, at the same time approaching the reef. The depth on this plateau extends from about ninety fathoms to about two hundred and fifty to three hundred. The rock of which it consists is a dark-brown, hard limestone, in which the corals and shells living on its surface, and to which it owes its formation, can frequently be recognized.

The fauna of this bottom is much richer than that of the first region. All the classes of the sea-invertebrates are fully represented: *Crustacea*, mollusks, (among which the most abundant are two species of Brachiopods, and the rare *Voluta Junonia* is not unfrequently obtained here living,) Echinoderms, particularly *Echinidæ* and *Ophuridæ;* also *Astræidæ* and *Holothuridæ*, but less abundantly; then quite a number of small corals and *Gorgonidæ*, mostly of very elegant form; finally, sponges and *Foraminifera.* Of truly vegetable forms we find only a few Nullipores and Diatoms, but no true *Algæ.*

A similar sea-bottom, but with a very steep slope, is formed on the north side of Cuba, to a depth of three hundred to four hundred fathoms, also inhabited by a rich fauna, which presents, however, considerable differences from the one just mentioned, notwithstanding the short distance between the two coasts.

Near the Bahama Banks, which our explorations have touched in but very few points, we found the steep slope covered with calcareous sand.

Foraminiferous calcareous bottom.—In great depths, as, for instance, in the straits of Florida, at the outward limit of the rocky bottom, and, where this does not exist, even in less depths, the bottom is covered by a chalk-like layer, which resolves itself, under the microscope, into a mass of

Foraminifera and their fragments, more or less comminuted. This formation extends almost uninterruptedly in the whole bed of the Gulf Stream, in the greater depths of the Gulf of Mexico, in the deep channels which intersect the Bahama Banks, and then up the Atlantic coast from about the hundred-fathom curve outward, or from the inner limit of the Gulf Stream, which nearly coincides with it, and so over the greater part of the Atlantic basin. The discovery of this formation belongs to the year 1853, when it was found almost simultaneously by Lieutenants Craven and Maffitt, then in the Coast Survey, and exploring the Gulf Stream. It became more extensively known, somewhat later, by the soundings made for the Atlantic telegraph.

The genus of *Foraminifera* most abundantly represented in this bottom is the Globigerina; hence the term "Globigerina bottom" is becoming generally used. Then comes in order of frequency *Rotalina cultrata;* then several *Textulariæ*, *Marginulinæ*, &c. It is now pretty generally admitted that these Rhizopods live and die in these great depths, although formerly false ideas of the effects of pressure, of the want of light, &c., seemed to militate against the supposition. But that animals living near the surface contribute also a not inconsiderable proportion, is proved by the numerous shells of Pteropods, occasional teeth of fishes, &c.

Of higher animals the lead has frequently brought some fragments. In one case Mr. Pourtales brought up a specimen of not quite two cubic inches from a depth of five hundred and ten fathoms, and found in it distinct fragments of at least forty-eight different species, among which were twenty mollusks. Since we have used the dredge they have also been observed living. Small unattached corals, delicate Alcyonians, Ophiurians, Annelids, Mollusks, and *Crustacea* are commonly found in the dredge; very rarely a small fish. We obtained not unfrequently the curious living Crinoid, *Rhizocrinus lofotensis* of Sars, found by him off the coast of Norway, obtained also recently by Carpenter and Thomson in the vicinity of the British Islands, and this summer by Smitt and Ljungmans, on the newly discovered Josephine Bank, not far from the Azores. These four localities are within the limits of the Gulf Stream and of its branches.

This whole bed is an immense layer of chalk, to which the organic life developed on its surface is constantly adding, while nearer shore the faunæ of the littoral and deep-sea regions, with their numerous corals and shells, contribute to the formation of limestone of various characters, such as Oolite, Muschelkalk, Coral Rag, and conglomerates from beds broken up and reconstructed.

We must mention one formation, the origin of which, in former geological periods, was due to *Foraminifera*, and which is at the present day in process of formation in certain parts of the sea-bottom.

Greensand formation.—Ehrenberg made, as is well known, the interesting discovery that the so-called greensand or glauconite consists of the casts of *Foraminifera*. That this process is still going on at the bottom of the ocean, near our coasts, was discovered by Bailey, from the examination of our specimens of bottom. In some of them the whole process can be followed in the most interesting way. Thus we find, side by side, the tests perfectly fresh, others still entire, but filled with a rusty-colored mass, which permeates the finest canals of the shells like an injection. In others, again, the shell is partly broken away, and the filling is turning greenish; and finally we find the casts without trace of shell, sometimes perfectly reproducing the internal form of the chambers; sometimes, particularly in the larger ones, cracks of the surface or conglomeration with other grains obliterates all the characters. They even coalesce into pebbles, in which the casts can only be recognized after grinding and polishing.

Mr. Pourtales has succeeded, by the examination of many specimens, in indicating on the map a region in which this formation is particularly developed. It is situated off the coasts of Georgia and South Carolina, in fifty to one hundred fathoms, pretty much on the border between the silicious and the foraminiferous sea-bottoms. Now and then the greensand occurs also in greater depths under the Gulf Stream, but apparently without regularity. Why this process of transformation should occur only in particular localities is as yet unexplained. It is easy to distinguish this fresh-formed greensand from the tertiary one off the coast of New Jersey, by the greater number of perfect tests of Foraminifera mixed with it.

Our researches have extended to about seven hundred fathoms; much greater depths do not occur in the field examined. Life was found as deep as we went; not abundantly, to be sure, but we have reason to believe that the constitution of the bottom, more than the actual depth, is the

cause of the diminution; for the change occurred very abruptly in passing from the rocky to the foraminiferous bottom.

With regard to the physical conditions under which these animals live, it is well known that the temperature in great depths is very low, not many degrees above the freezing-point. A certain degree of light probably penetrates. The *Crustacea*, Annelids, and mollusks found there have well-developed eyes, if anything, larger than those of their congeners of the littoral zone.

The results of the expeditions of 1867–'68 have been partly worked up and published in the "Bulletin of the Museum of Comparative Zoology in Cambridge." The collections made this year and the still undetermined parts of those of former years are in hand for description. The Echinoderms have been reported on by Alexander Agassiz, Theodore Lyman, and Assistant Pourtales, and a comprehensive report of great interest has been made by Professor Agassiz. (Appendix No. 10.)

One of the most important results, so far, is the fact that the Corals and Echinoderms of the deep-sea region bear a type having many points of resemblance with the tertiary and cretaceous faunæ. Furthermore, that many forms have a very extended geographical distribution, as we have seen above in the case of Rhizocrinus. How this distribution has taken place we shall not be able to know until we understand better the currents of the ocean, particularly in the depth.

The impulse given to deep-sea investigation is a vigorous one, and has received a hearty support from several governments. Thus, in the last two years, Carpenter, Thomson, and Jeffreys, in the Lightning and Porcupine, have explored the sea-bottom along the coast of Europe, from the Faroe Islands to Cape Finisterre, and have sunk their dredge to the great depth of 2,500 fathoms. Smitt and Ljungmans, in the Swedish frigate Josephine, dredged from the coast of Portugal to the Azores, and thus across the Atlantic Ocean to America; and a Norwegian frigate is about to visit the coast of Brazil for similar purposes.

Let us hope that other governments will follow, and employ some of the ships of their navies in these interesting developments.

APPENDIX No. 12.

ON THE USE OF THE ZENITH-TELESCOPE FOR OBSERVATIONS OF TIME, BY J. E. HILGARD.

The zenith-telescope, or equal-altitude instrument, has now, during twenty years, been used very successfully for determinations of latitude, and, with Americans, has become the favorite field-instrument, both on account of the precision of its results and of the facility of observation. Its power for the determination of time has not, however, been developed, although well adapted for the purpose. Gauss, indeed, has shown, long since, how observations of stars on the same horizontal circle, or at equal altitudes in different verticals, would yield the co-ordinates of time and latitude, and has solved the problem in its most general form. But the want of a sufficient number of well-determined stars prevented him from developing the most advantageous special cases of the method, requiring the minimum of computation, viz, the determination of latitude by equal altitudes on the meridian, north and south of the zenith, and that of time by equal altitudes on the prime vertical, east and west of the zenith.

When we consider the great precision with which the zenith-telescope enables us to observe *equal altitudes*, we will perceive at once its applicability to that purpose. Here, as in the observations for latitude, we require a number of well-determined stars grouped according to certain conditions. The abundance of such positions that is afforded by recent catalogues of stars renders of easy application methods which would formerly have failed for want of such *data*, and which, for that reason, were not developed.

If two stars of precisely the same polar distance, but differing some hours in right ascension, had been observed at the same zenith distance, on opposite sides of the meridian, one to the east, the other to the west, it is obvious that the mean of their right ascensions would express the right ascension of the zenith, or the sidereal time corresponding to the mean of the observed times. Further, if there were but a small difference in polar distance, the corresponding change in the hour-angle, or correction to the time, could be expressed by a simple differential formula.

Since the determination of time by means of zenith distance is most advantageous when the star is on the prime vertical, we will first consider the proposed method under that condition, which, moreover, affords the practical convenience that an opening along the east and west line of the observatory, if the instrument is housed, will afford the command of all the stars that may be selected. In the temporary observatories used in the Coast Survey, the ridge of the roof runs east and west, and it is very easy so to construct it, with a double ridge-beam, as to have an opening of six inches which will be covered by a folding door.

We propose, then, to select a pair of stars so conditioned that they will pass the prime vertical at nearly equal zenith distances on opposite sides of the meridian, at no great interval of time from each other. This requires that their polar distance should be nearly equal; moreover, the stars must be south of the zenith in order that they may pass the prime vertical at all, and yet sufficiently far north of the equator in order that they may cross the prime vertical at an altitude beyond the influence of irregular refraction. This somewhat limits our selection. Before defining the limits more precisely, we will now consider the formulæ required for computation.

We require to know approximately the hour-angle, H, and the zenith distance, ζ, for the purpose of making the selection and preparing for the observations. We have given the co-latitude, λ, the polar distance, Δ, and the right angle at the zenith.

We have for the hour-angle—

$$\cos H = \cot \Delta \tan \lambda$$

For the zenith distance—

$$\cos \zeta = \cos \Delta \sec \lambda$$

We further require differential expressions for the variations in the hour-angle arising from a change in polar distance, and from that change in zenith distance which is expressed by the level correction. As the zenith distance gives the most convenient expressions, and is also required for setting the instrument, we employ it for that purpose, and obtain readily—

$$d\,H = d\,\Delta\,\frac{\tan\lambda}{\sin\Delta\sin\zeta},$$

$$d\,H = d\,\zeta\,\frac{\cos\zeta}{\cos\Delta\tan\lambda}$$

As we have in the first expression the sine of the zenith distance as a divisor, we are warned not to come too near the zenith in this method of observing for time, lest the error in the difference of polar distance be greatly exaggerated in the correction of the time. Assuming the uncertainty of that difference at one second of arc, we must not allow the numerical value of the factor $\frac{\tan\lambda}{\sin\Delta\sin\zeta}$ to exceed three, if we would not admit an uncertainty greater than two-tenths of a second of time. Hence we should not choose stars that cross the prime vertical nearer to the zenith than about 30°.

The problem would take a more favorable form in this respect if we could observe the stars precisely on the prime vertical, and measure with the micrometer the difference of zenith distance due to that of polar distance. But, as we have no means of fixing the instrument in that vertical, it is best to accept the simpler mode of using equal altitudes. We shall, however, hereafter consider more fully the mode of observing just mentioned.

Let us now illustrate the proposed method by an example. Wishing to make observations for time in that way at Washington, in October, 1869, we proceed as follows:

Taking the latitude at 38° 53′ 40″, and adopting 75° as the greatest polar distance to be used, in order not to approach too near the horizon, we prepare for the selection of stars by computing a table of zenith distances and hour-angles, as given below. This may be done by computing for every second degree and interpolating the intermediate values. This is the only part of the operation that may appear laborious to observers, but, as the factors $\tan\lambda$ and $\sec\lambda$ are constant, the computation can be made very readily. Arresting the computation when a zenith distance of 30° is about reached, we form the following table:

Zenith distance and hour-angle of stars on the prime vertical of Washington, 38° 53′ 40″.

Δ	ζ		H. in arc.		H. in time.		
°	°	′	°	′	h.	m.	s.
75	65	39.4	70	36.0	4	42	24
74	63	57.6	69	10.8	4	36	43
73	62	14.9	67	43.8	4	30	55
72	60	31.1	66	14.9	4	25	00
71	58	46.0	64	44.1	4	18	56
70	56	59.7	63	10.9	4	12	43
69	55	11.8	61	35.2	4	06	21
68	53	22.3	59	56.7	3	59	47
67	51	30.9	58	15.2	3	53	01
66	49	37.5	56	30.2	3	46	01
65	47	41.7	54	41.3	3	38	45
64	45	43.2	52	48.1	3	31	12
63	43	41.5	50	49.9	3	23	20
62	41	36.5	48	46.2	3	15	05
61	39	27.2	46	35.9	3	06	24
60	37	13.2	44	18.1	2	57	13
59	34	53.2	41	51.5	2	47	26
58	32	26.2	39	14.0	2	36	56
57	29	50.3	36	23.5	2	25	34

Determining next the sidereal hour at which it is proposed to commence operations, we make our selection from the British Association's catalogue of stars by choosing a well-determined star of suitable polar distance, having a right ascension less than the proposed sidereal time by the approximate hour-angle, and then looking for a mate of nearly the same polar distance in right

ascension greater by twice the hour-angle, the former being the western, the latter the eastern star of the pair.

The following table, giving a selection of eligible pairs from a much larger number yielded by the catalogue, will show that there is an abundant choice.

Table of selected pairs.

	Star B. A. C.	α	Δ	H	Sidereal time when on prime vertical.	ζ approx.
		h. m.	° '	h. m.	h. m.	° '
W.	431	1 19	71 26	4 21	20 58	59 28
E.	5702	16 49	71 21		21 10	
W.	707	2 10	70 42	4 17	21 53	58 14
E.	6030	17 43	70 42		22 00	
W.	1390	4 22	71 39	4 23	23 59	60 00
E.	6783	19 41	71 46		0 04	
W.	1376	4 20	71 06	4 20	0 00	59 00
E.	6794	19 43	71 10		0 03	
W.	1934	5 55	70 18	4 14	1 41	57 32
E.	7528	21 33	70 20		1 47	
E.	5900	17 20	69 49	4 12	21 32	56 40
W.	577	1 47	69 50		21 35	
W.	556	1 42	68 22	4 02	21 40	54 06
E.	6106	17 56	68 24		21 58	
W.	644	1 59	68 00	4 00	21 59	53 26
E.	6231	18 15	68 05		22 15	
E.	6387	18 40	69 35	4 10	22 50	56 22
W.	1045	3 15	69 43		23 05	
E.	7275	20 52	68 10	4 01	0 53	53 32
W.	1637	5 11	68 01		1 10	
E.	6116	17 57	67 04	3 53	21 50	51 37
W.	581	1 48	67 03		21 55	
E.	6827	19 48	66 15	3 48	23 36	50 08
W.	1147	3 37	66 18		23 49	
E.	6835	19 49	66 01	3 46	23 35	49 38
W.	1095	3 26	65 58		23 40	
W.	1107	3 29	67 13	3 55	23 34	51 57
E.	6866	19 53	67 15		23 48	
W.	1527	4 49	66 15	3 48	1 01	50 08
E.	7437	21 18	66 17		1 06	
E.	7585	21 40	67 39	3 57	1 37	52 40
W.	1915	5 53	67 36		1 56	
W.	796	2 29	65 55	3 46	22 42	49 30
E.	6542	19 00	65 57		22 46	
E.	6676	19 23	63 30	3 27	22 50	44 42
W.	813	2 32	63 30		23 05	
E.	6940	20 05	63 32	3 28	23 33	44 49
W.	980	3 02	63 35		23 34	
E.	7461	21 22	62 57	3 23	0 45	43 36
W.	1326	4 12	62 57		0 49	
W.	1863	5 45	62 25	3 19	2 26	42 32
E.	8097	23 09	62 28		2 28	
E.	6648	19 19	60 38	3 03	22 22	38 35
W.	514	1 34	60 36		22 31	
W.	8206	23 27	59 23	2 51	20 36	35 50
E.	6147	18 02	59 27		20 53	

From this table the observer would arrange his scheme of work to suit the other observations he had in hand. For the purpose of determining the correction of the chronometer for observations of latitude or azimuth, he would content himself with observing three or four pairs in an evening, and in order to select these he would not be under the necessity of forming so extensive a table as above given, but could readily find from the catalogue suitable pairs for the special times at which he wished to make the determinations of time.

The following may serve as an example of an observation:

Example of observation.

WASHINGTON, *October* 15, 1869.

The passages of the star are observed over the fixed horizontal wires, making the micrometer readings 10, 20, 30, and over the micrometer-wire set at 15 and 25 turns. Instrument set to zenith distance 42° 33′. One division of level = 1″. The observations are made near the middle vertical wire, the instrument following the star in azimuth by means of the tangent-screw.

Star.		Mics.	Chron. time.	Level.	
				E.	W.
			h. m. s.		
1863.	W.	30	26 44.0	26.5	28.0
(136 Tauri.)		25	27 04.3		
		20	2 27 24.5		
		15	27 44.8		
		10	28 05.0		
Mean....	......	......	2 27 24.52		
8097.	E.	10	28 33.1		
(61 Pegasi.)		15	28 53.5		
		20	2 29 13.7		
		25	29 34.0		
		30	29 54.2	30.0	24.5
Mean....	......	......	2 29 13.70	56.5	52.5

Computation.

		h. m. s.	° ′ ″
8097	A. R.	23 09 25.28	Δ 62 27 34.6
1863		5 45 08.21	62 25 24.0
Mean of A. R.		2 27 16.74	$d\Delta$ 2 10.6 = 130″.6

Arranging the signs for the form $E - W$, we observe that the star having the greater polar distance has also the greater hour-angle, and that if the eastern star have the greater polar distance, making $E - W$ positive, it will cross the prime vertical earlier. Therefore, in order to make the observation what it would have been if both stars had the same polar distance, we must add the correction for difference of polar distance—

$$d\,H = \frac{d\,\Delta}{15}\,\frac{\tan\lambda}{\sin\Delta\sin\zeta} = 18^{s}.01$$

to the sum of the observed times, or half of it to their mean, with the sign resulting from taking the polar distance of the western from that of the eastern stars.

Again, as to the level-correction, if the east end is too high, the zenith of the instrument is to the west of the true zenith, and the observation will be too late by a corresponding amount. The level-correction must therefore be applied with the sign resulting from subtracting the east readings from the west readings. The scale being numbered each way from the middle, we must take one-fourth the difference of the sums, and find the level-correction to be $-1''$, which, multiplied with

$\frac{\cos \zeta}{15 \cos \Delta \tan \lambda}$ gives $-0^{s}.086$ as the corresponding correction to the observed times. We have, therefore—

	h. m.	s.
Mean of observed times…… ……………	2 28	19.11
Correction for $d\,\Delta$……………………………		+09.00
Correction for level ………………………		− 0.08
Corrected mean of observed times…………	2 28	28.03
Mean of right ascensions …………………	2 27	16.74
Chronometer fast ………………………	1	11.29

The restriction to observation of equal altitudes near the prime vertical was adopted at the outset; from considerations of the more ready computation of the hour-angle and zenith distance in the right-angled triangle, and of the convenience of having a continuous opening in the field observatory, along the ridge of the building. Moreover, the determination of time by equal altitudes is most exact when made in the prime vertical.

It may, nevertheless, prove expedient to choose pairs of stars not so situated, especially such as can be found in the astronomical ephemeris, with the apparent places ready to hand. Of such pairs a larger number than might be anticipated may be found, having nearly equal polar distances, and sufficiently far apart in right ascension to yield a good determination of time. The following list has been selected from the American Ephemeris:

Star.	Right ascension.	Declination north.	Star.	Right ascension.	Declination north.
	h. m. s.	° ′ ″		h. m. s.	° ′ ″
α Androm …	0 01 37	28 22 02	ε Hydræ……	8 39 50	6 53 51
β Tauri ……	5 18 01	28 29 37	α Serpentis ..	15 37 48	6 50 23
Mean….	2 39 49	Diff. 7 35	Mean….	12 08 49	Diff. 3 28
θ Piscium….	23 21 19	5 39 34	α Leonis…..	10 01 24	12 36 23
α Can. Min…	7 32 26	5 33 30	α Ophiuchi…	17 28 51	12 39 28
Mean….	3 26 53	Diff. 6 04	Mean….	13 45 07	Diff. 3 05
α Androm …	0 01 37	28 22 02	12 Can. Ven…	12 49 53	39 01 35
β Geminorum	7 37 17	28 20 24	η Herculis …	16 38 24	39 10 23
Mean….	3 49 27	Diff. 1 38	Mean….	14 44 08	Diff. 8 48
ζ Arietis ….	3 07 22	20 33 26	η Bootis …..	13 48 26	19 03 19
γ Leonis…..	10 12 44	20 30 10	1 Pegasi…..	21 16 02	19 14 44
Mean….	6 40 03	Diff. 3 16	Mean….	17 32 14	Diff. 11 25
β Leonis…..	11 42 22	15 18 16	α Herculis …	17 08 40	14 32 31
γ Tauri ……	4 12 20	15 18 31	α Pegasi…..	22 58 14	14 30 04
Mean….	7 57 21	Diff. 15	Mean…	20 03 27	Diff. 2 27
ε Tauri ……	4 20 58	18 53 14	α Herculis …	17 08 40	14 32 31
η Bootis …..	13 48 26	19 03 19	γ Pegasi…..	24 06 30	14 27 19
Mean….	9 04 42	Diff. 10 05	Mean….	20 37 35	Diff. 5 12
φ Geminorum	7 45 28	27 06 07	ο Piscium …	1 38 29	8 29 50
α Cor. Bor…	15 29 08	27 09 27	α Aquilæ….	19 44 23	8 31 28
Mean….	11 37 18	Diff. 3 20	Mean….	22 41 26	Diff. 1 38

If we are observing in the open air, a selection from these pairs will be found the most convenient, requiring very little preparation. In a temporary observatory it may be found best to make small openings, with covers, for the stars that are selected to serve for the determination of time on a series of nights.

To illustrate the method we take the following pairs:

		h. m. s.		° ′ ″
α Andromedæ,	A. R.,	0 01 37	N. P. D.,	61 37 58
β Geminorum,		7 37 17		61 39 36

The observation is to be made at the sidereal time expressed by the mean of the two right ascensions, or about $3^h\ 49^m\ 27^s$. But it concerns us to have a convenient interval between the two observations, and we must choose the zenith distance somewhat greater, in order to obtain the eastern star earlier and the western star later. Taking, therefore, the hour-angle about two minutes larger, or at $3^h\ 50^m = 57°\ 30'$, and the mean polar distance, $61°\ 38'.8$, we computed the approximate zenith distance to be $48°\ 13'.6$ by the formulæ—

$$\tan M = \tan \lambda \cos H, \ \cos \zeta = \cos \lambda \sec M \cos (\Delta - M.)$$

In setting to this zenith distance we neglect the refraction which has the effect of slightly increasing the interval between the two stars reaching the middle wire.

Assuming the observed times to have been—

	h. m. s.
E.	3 48 23.30
W.	3 52 47.20
Mean,	3 50 35.25

we compute the correction for difference of polar distance by the differential expression—

$$d\,H = \frac{d\,\Delta}{30}\left(\frac{\cot \lambda}{\sin H} - \frac{\cot \Delta}{\tan H}\right)$$

dividing $d\,\Delta$ by 2×15, in order to convert it into time, and apply the half of it to the mean of the observed times, the sign $E-W$ holding good as before,

$$d\,\Delta \text{ being } +98, \text{ we find } d\,H = +2^s.00.$$

Furthermore, the level-readings indicating the west end high $1''.5$, we must add to the observed times—

$$d\,H = \frac{d\,\zeta}{15}\,\frac{\sin \zeta}{\sin \lambda \sin \Delta \sin H} = +0^s.13$$

and we have therefore—

	h. m.	s.
Mean of observed times	3 50	35.25
Correction for $d\,\Delta$		+ 2.00
Correction for level		+ 0.13
Corrected time by chronometer	3 50	37.38
Mean right ascension or sidereal time	3 49	27.00
Chronometer fast	1	10.38

The simplest and most direct mode of determining the time for equal altitudes is that of observing the *same star* on or near the prime vertical on both sides of the zenith. In order that the observations may be confined within convenient limits of time, the star should have a small zenith distance, or its declination must be nearly equal to the latitude of the station. The limit of zenith distance corresponding to any assumed limit of interval between the eastern and western observations can be readily computed, but it will practically suffice to say for our latitudes that the zenith distance should not exceed one degree. That the star should pass to the south of the zenith is most advantageous, but even if it passes to the north within that limit, the observation will be quite satisfactory, although, of course, it cannot be made on the prime vertical. The preparation for the work will be the same as already set forth, and as the observations are presumed to be made at precisely equal altitudes, the mean of the observed times, corrected for level-error, will correspond to the right ascension of the star.

It is worthy of note that both time and latitude may be determined with the zenith-telescope

by observations upon one star passing within a few minutes of the zenith, in the following elegant manner: The instrument being set to the zenith, turn it in azimuth to the east, and note the passage of the star over a wire rather low in the field; next, turn to the south, point the micrometer on it about 20^s before the meridian passage, read, turn the instrument to the north and again bisect the star about 20^s after meridian passage, and finally note the passage over the same wire, as before, as the star descends to the west. The mean of the east and west observations will give the time of the star's meridian passage, while the difference of the north and south observations will give the zenith distance on the meridian in terms of the micrometer. The level may be read in the several positions before or after the observations on the star.

We have referred to the plan of making the observations for time by measuring the difference of zenith distance in the prime vertical with the micrometer, when using two stars of unequal declination.

The general scheme would be to correct the difference of time by means of the measured difference of zenith distance, and thus reduce the observation to the case of equal altitudes of stars having the same declination. But the details of the observation, as well as of the reduction, would be much more complicated than in the cases that we have developed, and since no lack of stars, suitable for those methods, is to be apprehended, it would not be useful to explain more fully the plan last mentioned.

The foregoing method has been sketched chiefly with the view of setting forth that the transportation and mounting of a transit-instrument may be dispensed with, when the determination of time is only required for the purpose of reducing latitude observations made with the zenith-telescope, and those of the azimuth of geodesic lines which are usually combined with the former. When the latter only are required, the theodolite itself will serve conveniently for the determination of time, used either as a transit or for equal altitudes in the manner above described.

APPENDIX No. 13.

ABSTRACT OF A PAPER READ BEFORE THE NATIONAL ACADEMY OF SCIENCES, APRIL 16, 1869, ON THE EARTHQUAKE-WAVE OF AUGUST 14, 1868. BY J. E. HILGARD, ASSISTANT, COAST SURVEY, IN CHARGE OF OFFICE.

(This abstract has been prepared, during Mr. Hilgard's absence, from his notes.—C. S. P.)

The sheets of the self-registering tide-gauges of the Coast Survey at San Diego, Fort Point (San Francisco), and Astoria (mouth of the Columbia River), show, on the 18th of August, 1868, the most considerable earthquake fluctuations which have ever been registered in that way.

These were due to the great earthquake of August 13, the shocks of which were nearly vertical at Arica, Peru. At Arica the officers of the United States steamer Wateree report that the first shock began at $5^h\ 05^m$ and lasted till $5^h\ 15^m$; and that the first wave in the harbor began at $5^h\ 32^m$.

At San Diego the fluctuations began on the 14th at 2^h a. m. and reached a maximum of amplitude at $8^h\ 40^m$ p. m., and disappeared about the 20th at 6^h a. m. The greatest amplitude was 2.6 feet, and the period about 30 to 40 minutes.

At Fort Point the fluctuations began on the 14th at 3^h a. m., reached a maximum (which has some appearance of correspondence with that at San Diego) at $2^h\ 50^m$ p. m., and disappeared about noon on the 19th. The maximum amplitude was 1.8 feet.

At Astoria the fluctuations began on the 14th at $8^h\ 50^m$ a. m. The maximum was reached at $8^h\ 40^m$ p. m., and the irregularities disappeared about midnight on the 17th. The maximum was 1.1 feet.

The following letter has been received by the Superintendent of the Survey, showing the time and amplitude of the waves at Kodiak Island, Alaska:

"SAINT PAUL, KODIAK,
"*Alaska Territory, October* 18, 1868.

"DEAR SIR: Supposing that it would be of interest to you, I have the honor of reporting the occurrence, at this place, of an extraordinary ocean-wave, which took place between 10 o'clock a. m. and 2 p. m. on the 14th of August last.

"I was not here myself to witness it, and there was no special or accurate observation made of it; but from those who did witness it I learn that at the time of the first wave the tide was about one-third ebb—the tide here rises about ten feet—and in about half an hour it rose to about four feet above ordinary high water. It then receded, and afterward, at intervals of about an hour each, it would come and go, each time giving less and less.

"I observe by the papers that this was on the day succeeding the great earthquake in Peru, and no doubt this wave was caused by it, and, being so marked at this distant point, it will no doubt prove an interesting fact to you.

"I will make further inquiries, when I have an opportunity of so doing, whether any wave was observed at Ounalaska, Saint Paul, or any other islands westward of this.

"Very respectfully, your obedient servant,

"JNO. C. TIDBALL,
"*Major Second Artillery and Brevet Brigadier-General.*

"Professor BENJAMIN PEIRCE, LL.D.,
"*Superintendent United States Coast Survey.*"

Tabulating these facts together with others which have been derived from other sources, we have—

	Distance from Arica.	Local time, first wave.	Longitude from Arica.	Arica time, first wave.	Time of transmission.	Nautical miles per hour.	Mean depth of ocean.
	Miles.	*d. h. m.*	*h. m.*	*d. h. m.*	*h. m.*		*Feet.*
Arica	....	13 5 32	....	....	....	....	....
San Diego	4,030	13 14 00	2 27	13 16 27	10 55	369	12,100
Fort Point	4,480	13 15 00	3 28	13 18 28	12 56	348	10,800
Astoria	5,000	13 20 50	3 33	13 24 23	18 51	265	6,200
Kodiak	6,200	13 22 00	5 32	13 27 32	22 00	282	7,000
Rapa	4,057	13 11 30	4 56	13 16 26	10 54	372	12,200
Chatham Island	5,520	14 13 30	7 03	13 20 33	15 01	368	12,100
Hawaii	5,460	13 14 00	5 42	13 19 42	14 10	385	13,200
Honolulu	5,580	13 12 00	5 50	13 17 50	12 18	454	18,500
Samon Island	5,760	14 14 30	6 40	13 21 10	15 38	368	12,100
Lyttleton	6,120	14 16 45	7 48	14 00 33	19 01	322	9,200
Newcastle	7,380	14 18 30	9 12	14 03 42	22 10	332	9,800
Sydney	7,440	13 20 00	9 13	14 05 13	23 41	314	8,800

The superior depth of the Pacific in its eastern equatorial part, which there was otherwise good ground for believing in, is here made manifest. The depth in the northern part also seems very small.

APPENDIX No. 14.

SOLUTION OF THE "THREE-POINT PROBLEM" BY DETERMINING THE POINT OF INTERSECTION OF A SIDE OF THE GIVEN TRIANGLE WITH A LINE FROM THE OPPOSITE POINT TO THE UNKNOWN POINT. BY A. LINDENKOHL, CHIEF DRAUGHTSMAN, COAST SURVEY OFFICE.

(See figures on Plate No. 26.)

Let abc be the given triangle, d the unknown point, and $bdc = \alpha$, $adc = \beta$, the given angles; it is then proposed to find the position of the point e at which the lines ab and cd intersect.

a' and b' being the points of intersection of circles drawn through b, d, c, and a, d, c, we have—

in the circle acd:	$ae \times b'e = ce \times de$
in the circle bcd:	$be \times a'e = ce \times de$
hence,	$ae \times b'e = be \times a'e$
substituting	$a'e \pm a'a = ae$
and	$(a'e \pm a'a)\, b'e = (b'e \pm b'b)\, a'e$
	$a'a \times b'e = b'b \times a'e$
or,	$a'a : b'b :: a'e : b'e$
and	$a'a : b'b :: ae : be$

According to this formula the point e is found by dividing the line ab into two parts, ae and be, which bear the proportion of $a'a$ to $b'b$ and have the same direction as $a'a$ and $b'b$ respectively. a and b being the angles of the given triangle at a and b, the ratio $aa' : bb'$ is represented by ($\text{cotg}\ a - \text{cotg}\ \alpha$) : ($\text{cotg}\ b - \text{cotg}\ \beta$).

APPLICATION TO THE PLANE-TABLE.

Let A, B, C, be points in the field whose projections a, b, c, are given; and let D be the point whose projection, d, is sought.

The point a' is obtained by making $ba'c =$ BDC, for $ba'c = bdc =$ BDC. (This is done by directing the sight of the alidade upon B while the ruler is placed upon the line ab, and with this position of the table drawing a line through C and c.) The point b' is similarly obtained by making the angle $ab'c =$ ADC.

To find the point e, divide the line ab in the ratio of $aa' : bb'$.* This may be done by drawing a line $a'f$ through a' parallel to ac; also one $b'f$ parallel to bc, and joining C and f. Or, erect parallel ordinates upon a and b, making them equal or proportional to $a'a$ and $b'b$, on the same or different sides of ab, accordingly as the direction of aa' and bb' are the same or opposite, and join the ends of these ordinates.

* There are two points, one within and one outside of ab, which will satisfy the condition of $aa' : bb' :: ae : be$, as long as the sign or direction of aa' and bb' is left indefinite. It is easy to ascertain the correct point by observing that it must be on the same side of a with a' and on the same side of b with b'.

APPENDIX No. 15.

REPORTS CONCERNING MARTHA'S VINEYARD AND NANTUCKET.

REPORT OF PROFESSOR HENRY L. WHITING ON EDGARTOWN HARBOR.

BOSTON, MASSACHUSETTS, *January* 2, 1872.

DEAR SIR: In compliance with your instructions of 18th July last, I proceeded to Edgartown, Martha's Vineyard, to make a survey of the changes in the topography of the harbor for the purpose of comparing the results with those of my former surveys of this locality, and in connection with the physical surveys of Professor Mitchell, to ascertain, if possible, the effect of these changes upon the harbor.

The comparison of the surveys just made with those of previous dates—1846, 1854, 1855, and 1856—giving intervals of fifteen and twenty-five years, affords data for most interesting study, and gives an accurate exhibit of the action of waves and currents along this section of the coast.

In his former and late reports, Professor Mitchell has stated the peculiar physical relation of the tides of the Vineyard and Nantucket Sounds to those coming upon the south shores of the islands of Martha's Vineyard and Nantucket, and the circulation of currents through Edgartown Harbor, and the former opening in Cotamy Beach. I will not, therefore, discuss these subjects in my report, but merely give their effects as they appear.

At the time of my first survey, in 1846, the opening through Cotamy Beach was at the eastern corner, so to speak, of the bay, but not beyond the southwestern point of Chappaquiddick Island; in fact, the inlet was formed by this point of Chappaquiddick and the east end of the beach, and was about two thousand feet in width. Within the opening, however, were two small sand islands, with channel-ways between and on either side of them. This condition of the inlet corresponded in its general location and width to that shown on the maps of Des Barres of 1776.

In 1856 I was ordered by Professor Bache to make a resurvey and examination of this same locality, in order to determine the position and dimensions of the new opening which was reported to have been made by a then recent storm.

By this survey I found great changes had taken place since 1846. The old inlet had worked about one mile to the eastward of its former site, and the point of the beach had lapped by the end of Chappaquiddick over half a mile. The shore of this island, along its southwestern face, had washed away to the extent of about 2,300 superficial feet. This action had changed the character and capacity of the inlet from a broad opening, of 2,000 feet, directly opposite the waters of the bay, to a much narrower channel confined between the fast land of Chappaquiddick and the beach. This water-way between the ocean and the bay was about 3,000 feet in length and about 500 feet in width.

The new inlet had broken open about opposite the middle of the bay, and was, at the time of my survey—1856—about 1,400 feet in width, thus restoring the total inlet capacity, so far as width was concerned, to nearly that of the old inlet of 1846.

Since 1856 we have had no determination of the beach until the surveys made last summer, when it was found to extend across the entire south part of the bay, with no opening into the ocean. We have, however, quite reliable local information concerning the intermediate changes, from which we have obtained the following general facts:

Soon after the "west opening," so called, of 1856, was formed, the "east opening" closed, and the new west opening, following the law of motion which seems to govern all the inlets on the south side of the island, began its movement eastward, and continued until it reached the site of

the former inlet of Des Barres, and of the Coast Survey of 1846, passed on to the site of the inlet of 1856, and still continued working eastward until the point of beach forming its outer chop reached a point in line with the general trend of the east shore of Chappaquiddick. Here the rapid tidal currents of Muskeget Channel checked its further progress. For a time the tidal currents into and out from Cotamy Bay battled with the sea-dash upon the shore, the latter gradually gaining ground upon the current power, crowding the beach further and further toward the main land of Chappaquiddick and narrowing the water-way between them, until, at the occurrence of a storm and tide favoring the action, the most easterly portion of the beach was beaten in upon the island by the ocean waves and the inlet closed. This happened in 1869, since which time the beach has remained intact, and all the tidal action and influence of a southern inlet, connecting the waters of the ocean and the sound through the channels of Edgartown Harbor and Cotamy Bay, have ceased.

There is the tradition of a continuous beach, and the closing of all inlets, as at present, in the early part of this century; and that people passed with teams from the main island to Chappaquiddick, but that the link was only temporary, a new opening breaking through the beach again in a few months after it was closed. With this exception, there is no record or tradition of the non-existence of an inlet through Cotamy Beach since this section of the coast has been known.

It is an interesting and important fact that we are able so accurately to determine the extent and nature of the changes which have occurred in this locality within the last twenty-five years, particularly in this beach, which is a type of many others along the sandy portions of our sea-coast, and presents much the same barrier against the encroachment of the sea, preventing the wasting action of storm-waves from extending into bays, lagoons, and ponds.

The length of Cotamy beach, from east to west, is about three and a half miles, and its average width about 450 feet. As shown by my first and last surveys, this beach has been beaten bodily northward a distance about equal to its width. As this beach has re-formed its general natural slopes while changing its position, we find a present depth of about 8 feet below high water over the area occupied by the beach itself in 1846, and also a corresponding depth on the inside of the beach; so that, in determining the amount of sands which have been moved, we must take them from above the plane of about 6 feet below high water. The average height of the beach above high water is about 8 feet. This gives a gross amount of about 116,500,000 cubic feet. In other words, a bank or mole of sand, 18,500 feet in length, 450 feet wide, and 14 feet high, containing 116,500,000 cubic feet, has been beaten in upon the bay and shore, by the steadily encroaching action of the ocean-waves, in a period of twenty-five years, a distance of 450 feet. This is not a case of any great convulsion or powerful current action. It is but a fair illustration of the gradual but unceasing *waste* which is going on upon such shores.

The island of Martha's Vineyard was probably visited and even settled upon by the early colonists. How great must be the contrast of the present shores with those they then explored, when we consider that, according to the ratio of change, Cotamy Beach must then have been 4,500 feet to the seaward of its present line!

In extending my survey westward from Cotamy along the main shore of the island, I found the same encroachment of the ocean going on. Two ponds of some acres in extent, and having local names, were, at the time of my survey in 1846, about 450 feet back from the shore-line. These ponds are now entirely obliterated. The site of one is now occupied by the sand-hills of the beach, while a small tract of marshy ground marks the inner borders of the other. I found no important changes in the inner shores of Cotamy Bay, or at points not under the immediate influence of the ocean forces.

With regard to the question of opening Cotamy Beach by artificial means, and thus restoring the former regimen of the bay and harbor, there seems to be but one answer to be given—it should be done at once.

The great value of Edgartown Harbor as one of shelter, and the *only perfect shelter*, within reach of the mass of vessels sometimes caught by bad weather in the dangerous approaches to Cape Cod; the importance of an inlet or passage-way from the harbor southward for the smaller pilot-boats peculiar to the island, which in certain winds and storms can safely and quickly reach vessels needing a pilot off Muskeget Channel, *through this southern inlet*, when it would be *impossible* for them to round Cape Poge, or reach the ground of danger by any other route; the fishing inter-

ests of Edgartown and its vicinity—an interest of much value, shared by a large proportion of the population, and so seriously affected by the loss of this safe and direct pathway to their fishing-grounds—all call for action and relief in the matter of this closed inlet.

The most favorable point at which to re-open Cotamy Beach seems to be at or near the west end or head of the bay.

The arguments in favor of this location are as follows:

1st. The greater length of time that the inlet will probably remain open, assuming that it will move from west to east as fast, and close as soon after reaching its eastern limit, as the former inlets have done.

2d. The fact that this contracted section of the bay, by confining the tidal currents between the main land of the island and the beach, as they flow to and from the actual inlet, favors the formation and maintenance of a channel, through the shoal ground bordering the beach, into the deeper waters of the bay.

3d. Economy in cutting through the beach, as the cross-section at this point is about the minimum.

Although an opening through the beach sufficient to merely start the water running, if made at the time predicted by Professor Mitchell, may, and probably will, create a natural inlet, and such an inlet may answer the physical demands required to restore the tidal circulation through the harbor; still, the uncertainty of a single tide doing the required work, and the contingency of an intervening storm or ocean swell preventing the continued action of the succeeding tide, render the scheme of depending upon the scouring power of the tide alone a questionable one, unless accompanied by a prepared pathway for it as far through the beach as practicable, and of such a width as shall at once secure, when opened, a stream of considerable volume.

Apart from the physical importance and effect of opening an inlet through the outer beach, there are difficulties of navigation which such an inlet only would not relieve.

As seen on the map or sketch which Professor Mitchell and myself jointly append to our reports, there is a range of shoal ground bordering the beach, and extending from east to west along the entire south front of the bay. Professor Mitchell has stated in his report that this shoal ground has increased, within the last fifteen years, by the amount of about one million of cubic yards. This coincides with the popular opinion of the constant accumulation of material upon this ground, which is now so extensive and so shoal that it is difficult for the peculiar class of boats required for the outside fishing and pilotage to cross it; in fact, they cannot do so, except by one or two tortuous and imperfect channels.

If a channel-way through this shoal ground were made in connection with a new inlet through the beach, it would, of course, give great relief to the boating interest, both for pilotage and fishing. Here again the western section of the bay, before alluded to, presents naturally favorable ground for such a channel by improving what was once, probably, a natural channel leading to some former inlet.

The question of how much this pilotage and fishing interest are worth, or what the value of the former may be to the general security of navigation, I will not presume to answer. It is not, however, an unreasonable supposition, that, within one year from opening an inlet and making such a channel-way, a vessel in distress outside may be saved by a pilot reaching her through this channel, and that the value of the vessel and her cargo may be worth as much or more than the amount it will cost to make the channel-way. This is apart from the question of the saving or loss of life.

In connection with this view of the harbor question, and in conclusion of the general subject, I have made some estimates concerning such a channel and inlet as I have named, which I submit for your consideration as suggestive items.

As a basis for the general dimensions and character of a channel and inlet as proposed, I have taken a width about equal to the narrowest section of the natural passage-way between the harbor and bay, which is about 300 feet. This is not wider than desirable for a beating channel. The depth is regulated by the class of boats in general use, which require about 4 feet at mean low water.

As before stated, there are, in this part of the bay, the traces of a former channel through this shoal. By following the general course of this old channel, and removing such portions of the

shoal as in places now block it up, a passage-way 300 feet wide and four feet deep may be obtained by the excavation of about 41,000 cubic yards of the material of the shoal.

A corresponding excavation through the beach to the level of mean high water only, which is probably all that will be needed to insure a successful inlet, will require the removal of about 14,000 cubic yards of sand. * * * * * * *

Upon the map, before referred to, which accompanies Professor Mitchell's and my reports, I have shown the outlines of the beach and inlets as they have been determined by the several surveys which I have made. These surveys have all been based upon the original triangulation, and referred to the same base-lines, so that the changes shown are *absolute.* The last survey, although not involving much detail, required considerable time and labor in its execution. The very changes which it was its purpose to determine had caused the loss of all points and land-marks along the outer shore of the island, so that a new series of points, based upon the light-house and spires of Edgartown and the station on Sampson's Hill, had to be extended to the south shore of the island and to Chappaquiddick before the survey could be made. I had but a small party organization, and am indebted to Professor Mitchell and Mr. Marinden for many favors and much assistance in the execution of my field-work.

Very respectfully submitted.

HENRY L. WHITING.

Professor BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

REPORT CONCERNING VINEYARD HAVEN: ITS CHARACTER AS A PORT OF REFUGE AND ITS PRESENT CONDITION. BY PROFESSOR HENRY MITCHELL, IN CHARGE OF PHYSICAL HYDROGRAPHY, UNITED STATES COAST SURVEY.

By a vote of the citizens of Holmes Hole Village, about a year since, the name of the place was changed to Vineyard Haven; and at the request of these citizens the Post-Office Department adopted this new name, which is rapidly supplanting the old one in popular use. The village really forms a part of the town of Tisbury, and vessels are registered in accordance with this legal designation, as heretofore; but in marine reports, the harbor is now called Vineyard Haven.*

This port is distinguished neither for its amplitude nor its security, but pre-eminently for its convenience. Situated at the junction of the Vineyard and Nantucket Sounds, where the sailing courses change their directions about three points, and where the currents are too strong, often, to be stemmed by the smartest vessel beating to windward, its position renders it invaluable as a halting-place, to wait for fair winds or the favorable moving of the waters.

The depth in the anchorage, while it is not so great as to cause delay in weighing ground-tackle, is ample for all classes of vessels. The access from the Sound is free and direct, so that a very large majority of the vessels that seek the anchorage employ no pilots. But ports free and direct of access are liable, as a general rule, to be so exposed in storms as to render them unsafe; and Vineyard Haven is not an exception in this particular. The ship that runs into this anchorage before a northeast gale leaves an open door behind her.

The comparative merits of different ports of refuge would form a very useful subject for a Coast Survey report, and I have long contemplated a trial upon this theme, in which the principal elements should be, *facility of approach, depth of water, protection from the sea, shelter from the winds,* and *character of the bottom.* But in this report I shall confine myself to a comparison between Vineyard Haven, and its rivals more especially; although I shall add some other ports incidentally.

In casting about for a type of perfection, in the way of a harbor of refuge, I find I cannot do better than take Provincetown, which seems to fulfill all the requisite conditions; and therefore I place the table for this port at the head of my list, and then follow with Vineyard Haven, which is the special subject of this report.

---

* Letter from Rev. D. W. Stevens, "Sailors' Free Reading-Room and Library."

Provincetown Harbor as a type.—To enter this harbor from the ocean, a vessel must make a sweep entirely round the compass. She can never, therefore, run in before the wind all the way; but with an easterly gale she finds herself in smoother water, and well sheltered, before close-hauling becomes necessary; and, with the wind northeast, she does not care to enter the harbor proper, but finds snug anchorage under the Truro shore—for Provincetown has not only a basin, but an outer roadstead, nearly 13,000 acres of which are sheltered from northwest round to southeast.

The limit of the inner anchorage on the side of the roadstead, we assume to be a line drawn from the extremity of Long Point to the westerly end of the State Dike, inclosing an area of 741 acres, over which there is a depth nowhere less than 18 feet at mean low water.

Table No. 1, and its illustrations upon our sketch, refer exclusively to the basin of Provincetown, it being deemed unnecessary to discuss the outer roadstead.

From our central position the land may be seen, from the deck of a ship, in every direction, and the average distance does not exceed one mile and a quarter; although the maximum fetch is nearly six miles in the direction which just clears Long Point.

In the most sheltered position, in which 18 feet at low water can be found, the ship at anchor is completely land-locked—the greatest fetch being less than two miles, and the average only about a half-mile at low water. In a harbor of refuge absolute quiet is not so essential as in a port of lading or discharging.

Upon our sketch No. 28 appear two sets of diagrams for the Provincetown exposure, which we give for the sake of comparing two methods of illustration. In the first set the old method used for plotting winds is retained, with some improvements suggested by Mr. Marindin; while in the second set the reverse method is employed, in accord with your own suggestion. In both sets the lengths of the arrows are measures of the exposure.

Since all the data of our table refer to the local effects of high winds, it has seemed proper to qualify the measures given for the "Fetch of the sea" by adding another column giving the "Angles of elevation" of the sheltering land. This last column has been computed from information supplied by Professor H. L. Whiting, who, with his own topographical surveys before him, has furnished the heights of the hills along our lines of direction. The angles being small, we have used their arcs as ordinates in plotting the profile of the land seen against the sky. It will be seen that the greatest shelter from winds is from west round by north to northeast, and that it is not deficient in southern quadrants.

The average elevation (all round the compass) is 16′, which is very large for a harbor of such great capacity.

Confining our attention still to the *basin*, or harbor proper, of Provincetown, let us inquire how many vessels it can accommodate. *First-rate men-of-war*, *merchant-ships*, and *miscellaneous merchant-vessels* are the three categories for which we should provide. I was a little puzzled about how much swing-room to provide for a man-of-war, having no experience myself, and finding but one authority, and that a foreign one, among my books; so I wrote to Rear-Admiral Davis, who gave me the clear statement which follows:

"The estimate of *Les ponts et chaussées* is sufficiently correct—32 acres.

"A vessel properly moored in a tideway occupies, in fair weather, but little more space than that in which she can swing freely; but in order that she may ride in perfect security at all times, she ought to have room enough to enable her to veer out the whole length of the cable, in bad weather, in any direction from which the wind may come.

"The *standard* cable's length is 120 fathoms = 720 feet, and this may be taken as the proper radius, although the whole of the cable cannot be paid out (the part between the hawse-hole and chain-locker remaining). This allows something for a spanker-boom projecting over the tackle. In the Navy we have longer cables for heavy ships, but the standard English measure will be more familiar to your readers."

The above decided me to assume a radius of 631 feet, after making allowances for the reserve of cable on board the ship and for the slant.

The depth of water required exceeds 23 feet at mean low water.

With these data I plot 12 first-rate men-of-war riding at storm-anchors in the basin of Provincetown.

Of merchant-ships, requiring at least 18 feet of water and 310 feet radius of swing-room, I find the number to be 85. Of miscellaneous merchant-vessels, with average radius 190 feet, I find the number to be 246. Although many merchant-vessels are of much less draught than 18 feet, I still have adhered to this depth for my miscellaneous list, because, as a general rule, vessels do not like to run inside of this depth, especially in heavy weather. In exposed roadsteads the sea will sometimes break in three fathoms, and in the sharp sea of many of our harbors a vessel heavily laden will plunge several feet as she falls.

It may be objected to my manner of reckoning swing-room that since vessels at anchor are swept by the wind in the same direction, the whole estimated circle is not required in each case. This criticism would be just, if, in practical experience, we could pack vessels into the port as carefully as we plot their circles upon our chart; and if vessels were all built alike, so as to have the same hold upon the water, and thus be liable to yaw over equal and corresponding sectors.

I do not include fishing-vessels in my third category, since their tonnage falls below the minimum taken. There have actually been seen 400 fishing-vessels at anchor in Provincetown at the same time. Whether all of them were within our assumed limits I cannot learn.

In a harbor of refuge, there is advantage in a clean strand, where vessels having lost their ground-tackle may be beached without danger, and where small vessels may be laid bare by the tide to undergo repairs. Provincetown Harbor possesses this advantage.

Vineyard Haven as a roadstead.—Having described the natural advantages of Provincetown Harbor, we are prepared to inspect Vineyard Haven, and to determine to what extent this anchorage is a suitable refuge for our large and increasing fleet of coasters.

In table No. 2, the exposures of this port are given for alternate points of the compass, from which it appears that the shelter is complete in the southeast and southwest quadrants; rather deficient in the northwest quadrant; and decidedly bad in the northeast quadrant. Indeed, there is no effective shelter from northeast round to east by north, although the Hedge Fence, Horse Shoe, and other shoals break somewhat the force of the sea in gales. But, we may certainly say, that with the wind from the open quadrant, vessels are no better off, as far as shelter is concerned, within the harbor limits than immediately outside in the sound.

Vineyard Haven is not then a *harbor*, properly speaking; it is a *roadstead*—not so safe as the roadstead off Provincetown, because the latter opens upon fairer quarters of the compass, and has a good safe harbor to leeward when the wind blows in. There is no shelter to be reached from Vineyard Haven, when the wind blows in followed by a heavy sea. There is an interior basin, called the Lagoon Pond, which has good depth of water, but the entrance is blocked and obstructed by sand-bars and small shingle, so that it is rarely sought.

In the sketch accompanying this report, I give the exposure of this port in comparison with that of Provincetown, and add a profile of the surrounding country. The angles of elevation are based on the same authority as that stated heretofore in respect to Provincetown, and may be trusted.

From our central position at Vineyard Haven, the maximum elevation is 1° 13′ in a direction due west. The maximum for Provincetown lies in the same direction and is about half as great.

The mean elevation for the western semicircle (south round by west to north) is for Vineyard Haven 32′ against 19′ at Provincetown. The mean for the southern semicircle is for Vineyard Haven 39′ against 9′ at Provincetown. The mean for the southeast quadrant (which is a storm quarter) is at Vineyard Haven 36′ against 7′ at Provincetown. The mean for the northeast quadrant is for Vineyard Haven 5′ against 17′ at Provincetown. In this, the quarter from which come our most frequent storms, Vineyard Haven falls below par, and for a majority of the storms fails altogether.

The survey of Vineyard Haven, executed during the past season by H. L. Marindin, Assistant, Coast Survey, enables us to measure very exactly all the advantages of this anchorage; and, by

comparison with the previous survey executed by our service in 1845, we are able to show the changes that have taken place.

The plane of reference adopted by us for correcting soundings was mean-low-water, while that adopted by Captain Blake in 1845 was one and six-tenths feet below. Our published chart, therefore, which was based on the earlier survey, has never fairly represented the capacity of the roadstead. In making comparisons, we have changed the datum of Captain Blake's survey so as to correspond with our own. This we could safely do, because the tidal observations, &c., of the earlier survey were all in our possession and in good order. Since 1845 the four and five fathom curves have moved out toward the Sound. This has resulted from a slight shoaling, probably due to the deposits of sand torn from East and West Chops by the sea. Professor Whiting's surveys of the past season, compared with those of previous years, show that these two Chops are losing ground at their extremities.

Within the four-fathom line *all the submerged contours have fallen back* in more or less degree. This remark is to be understood in a general sense, because there are points where the curves have advanced and others where they have retreated, the retreat being in excess. In my paper on the "Reclamation of Tide-lands," I offered as a theory, based on considerable observation and study of comparative surveys, that bays, exposed in the direction from which storm-winds are prone to blow, may be expected to extend; the contours within the influence of the waves having a tendency to fall back. Vineyard Haven, quite unexpectedly, furnishes me with another illustration, in a small way, supporting my views. Here, to be sure, the superficial area of the cove has diminished a little, not only because my limiting line, extending from East to West Chop, has fallen back a little, as the shores of these chops have washed away, but also because there has been a slight making out of the beach along the sides and near the head of the cove. As bounded by the 6-foot curve, the cove has retained about its old superficial area; as bounded by the 12-foot curve, it has enlarged 4 acres; and as limited by the 18-foot curve, it has enlarged from 515 acres in 1845 to 544 in 1871—a gain of 29 acres; so that, far from there having taken place any decline of this port, a real improvement has been in progress.

Only three first-rate men-of-war can be accommodated in the anchorage, and these must occupy the most exposed situations. Sixty merchant-ships can, however, now find swing-room in the anchorage, against 56 in 1845. Of miscellaneous merchant-vessels comfortably accommodated, I find the number to be 174; although Rev. D. W. Stevens, in charge of the "Sailors' Free Reading-Room," reports that 200 have actually been seen anchored at one time, and that the average tonnage of those may be set down at 220 tons each. Of my 174, I claim that six per cent. is the gain since 1845.

The dragging and fouling of ships in this anchorage are incidents exceedingly frequent. Vessels have had their masts cut away to prevent dragging, and one vessel is reported by Captain West, the light-keeper, as having foundered. The largest number of vessels driven on shore in a single storm is stated by Captain West at sixteen, and by Rev. D. W. Stevens at fourteen. The following extract from the report of the "Marine Agency of the Associated Press," for the year ending March 22, 1870, will be found interesting:

Arrivals.—Steamers, 52; ships and barks, 83; brigs, 627; schooners, 6,350; whalers, 14; yachts, 25; sloops, 8—total, 7,159; of which 410 were foreign, mostly British. Fishermen are not included in this list, but may be set down at 150 in the spring. Exclusive of the fishermen, the number of persons on these vessels may be set down at over seventy thousand.

In the foregoing I have endeavored to give, in brief, a fair view of the defects and merits of Vineyard Haven. By presenting first a model port of refuge, I have shown how far short of perfection the subject of my report falls, and yet I have been happily able to demonstrate that no decline of advantages is taking place. I have furthermore shown, from reliable information, the use made of this refuge by foreign and domestic vessels; and it remains to inquire whether this use is absolutely necessary, that is to say, whether other harbors in this neighborhood could not supply the place of Vineyard Haven or relieve it somewhat of its crowd.

Great Woods Hole.—I have often heard the question asked, "Why do not vessels run into Great Woods Hole, where perfect protection and quiet may be found, instead of crowding and crushing into Vineyard Haven?"

Great Woods Hole, so called, to distinguish it from a neighboring cove known as "Little Woods Hole," is the only perfectly sheltered basin on the Sound, into which eighteen feet of water can be carried at low tide. I have run into it many times; I know how perfectly tranquil it is during violent gales, and how excellent the holding-ground is; but I know also that the approach from the Sound is rendered difficult by the strong currents, and dangerous by rocky ledges on either hand. The pathway is well marked by buoys, but no stranger ventures into it without a pilot. Besides, it is too small to be a rival to Vineyard Haven were its approach never so good. Of the miscellaneous class of vessels to which I have referred above, only 18 can be so anchored as to swing free of each other, *i. e.*, a little over ten per cent. of the Vineyard Haven fleet when full, and not equal to the daily average of vessels seeking shelter.

Edgartown Harbor.—This is a noble port of refuge, and I give the table for its shelter at the close of this report. It is a resort for coasters in easterly gales of great violence, when it can be reached. But it lies several miles from the sailing-track of the Sound, and near no point of ordinary difficulty in the Sound navigation. Vessels bound westward run safely on through the Sound, past the mouth of this harbor, in the midst of easterly gales, with the expectation of reaching Newport or some of the shelters of Elizabeth Islands, and with Vineyard Haven as an alternative; while vessels coming from the westward scarcely appreciate the violence of an easterly gale until passing West Chop, where the expanse of the sea is thrown open, and then the utmost that can be attempted is to get into Vineyard Haven. As Edgartown is not a halting-place in ordinary weather, the sudden springing up of an easterly gale finds a large part of the fleet already anchored at Vineyard Haven.

Improvement of Vineyard Haven.—The employment of steamers in our coasting-trade has not only failed to diminish the sailing-fleet, but really does not seem to retard the steady increase of the latter; and one of the problems that must soon demand solution is, how to provide room and shelter for these vessels at Vineyard Haven. This problem I have studied with great interest, but not with much hope of success. I shall venture to touch lightly upon it, simply to indicate some initial steps in improvement.

Any one who has witnessed a rush of vessels into Vineyard Haven has observed that they all crowd in toward the center, frequently with mutual injury, while in the upper part of the cove, and along either side, there remain large spaces unoccupied. Of course this is due, in part, to the timidity of the skippers, who do not know the character of the bottom near the land; but, in greater part, it is due to forethought of anchorage-room on getting under way. I have seen the entrance to the roadstead so blocked with vessels at anchor that I have been afraid to attempt to run through the fleet into the unoccupied space (nearly thirty per centum of the whole anchorage) which lay higher up the cove.

If mooring-buoys were to be placed along the margin of the anchorage-ground, they would not only define the limits, so as to induce vessels to run boldly up the cove, but they would themselves supply means for securing at least fifty vessels in locations not now in common use. Proper police regulations could provide that vessels running in by day-light should leave the entrance free for those arriving after dark.

The form of the cove fits it peculiarly for this arrangement of buoys, since there are few irregularities in the submerged contours. The west shore is foul at some points out to the 10-foot curve, but the head of the cove and the east shore are generally free of rocks.

The mooring-buoys might be placed along the 15-foot (at low-water) curve, and thus accommodate ordinary coasters.

Of course vessels would usually be obliged to let go their own anchors, but they would prefer to do so near these buoys, to which, in case of a gale, they could make fast. They would also desire to make fast to them in getting under way.

The hope of providing shelter for this roadstead is small. The entrance must not be closed by jettees from the Chops; and the building of an isolated breakwater outside is impracticable, because of the great depth of water and the strong tide. The opening of a passage-way from the roadstead to the Lagoon is entirely practicable, and would not be very expensive, but this lagoon would freeze in winter, and remain frozen for long periods, perhaps. In this lagoon, as it now exists, without removal of its shoals, there is ample depth and area for forty-two merchant-vessels

swinging as free as in the roadstead, or quite double that number packed closely, as they could conveniently be in so quiet a place. The whole area of the Lagoon is a trifle over 400 acres, against 544 acres of roadstead (having depth of 18 feet and upward) in the haven.

I purpose, as before stated, to attempt ultimately a larger range of comparison among our harbors than properly belongs to a report like this; and I have here added a few sample tables, in order to elicit comments and criticisms, which may be useful to me hereafter. The table of "Anchorage-room," No. 17, is intended to be complete only for the harbors of Massachusetts, but I have added New York and Gardiner's Bays as instances of grand anchorage-grounds. In making out this table I have premised that a man-of-war requires 23 to 24 feet, and merchant-vessels 18 feet low-water depth at the entrance of the port. I have moreover provided that each vessel shall have free swing-room lying at storm-anchors.

As I have indicated heretofore, the amounts of anchorage-room do not, by themselves, furnish true measures of the comparative values of different ports. Aside from any question of geographical position, or particular relations to interior water-courses, the harbors of New York and Boston, fairly compared, seem to me very nearly equal, naturally, notwithstanding that the former has more than five times the anchorage-room of the latter.

Boston Harbor has more than enough anchorage-room; and since it is divided into basins by high islands and promontories, it furnishes perfect shelter from wind and sea. It, moreover, has no outer bar, but offers grand channel-ways from the open sea to the sheltered roadstead; and it has no strong currents to render the maneuvering of vessels difficult, or the movements of ice-fields dangerous. In these respects it is superior to New York. When, however, we come to compare the commercial basins of the two ports, the upper harbor of Boston sinks almost into insignificance alongside of that of New York. Originally the territory now covered by the city of Boston had more available water-front, in proportion to area, than New York, and the relative positions of the several basins could not have been more happily arranged for commercial uses. But the land transportation stole a march, for a while, on the maritime commerce, and, with hasty steps, threw bridges over the channels, shutting out from free access the best water-front of the city; so that now large sums of money are necessary to create and develop new frontages, and to enlarge the small basin that remains unobstructed by bridges, &c.

Within the limit of a circle of 2.92 nautical miles radius from the State-house in Boston, the natural frontage, which could have been made available, is twenty linear miles, to over one-half of which there is no longer free access. A circle of the same radius, with its center in New York City, and its circumference passing through Jersey City, Brooklyn, and Williamsburgh, includes fourteen and one-half miles of natural frontage, all of which remains free. Having no recent survey before me, I cannot state the total amount of improved frontage in the upper harbor of New York, but it does not fall short of twenty miles; while the improved frontage in Boston to which there is free access is only four and one-half miles.

The harbor commission has, however, entered upon a project which promises to supply the deficiency of wharf-room in Boston. You will appreciate the scope and spirit of this project after perusing the memorial addressed by the commission to the city of Boston, under date of May 13, a copy of which has been sent to you.*

Gardiner's Bay, with its perfectly sheltered tributary basins, is, perhaps, the best anchorage in the world. I could not adopt it, however, as my *type*, because of its compound character, but I call attention to it as offering every qualification for a port of refuge. Under the lee of the great natural mole, from which the bay takes its name, or in the tranquil basins round Shelter Island, a Spanish armada might find room enough to ride out a gale in peace.

I purpose to take up separately the fiörd harbors of Maine, Narragansett Bay, and Long Island Sound when I come to my full report, because either of these districts has harbor-room enough for an empire, and in this respect presents a strange contrast with our Southern, Gulf, and Pacific coasts.

I am indebted to my aid, Mr. J. B. Weir, for much of the work which my tables have required,

* See Supplement of Boston Daily Advertiser of May 15.

and I expect to rely very much upon his intelligent interest for going deeper into these subjects hereafter.

I need not explain to you the absence of wind-diagrams from our sketch, because I have sought your counsel upon the proper manner of constructing these so as to show the relations of winds and waves. It is patent that we should cast out low velocities, and recognize the fact that beyond a certain limit the waves do not increase with the duration of the gale. You have advised a further study of these points, and I, therefore, postpone the further consideration of this subject till more data are accumulated.

Very respectfully, yours,

HENRY MITCHELL,
Chief of Physical Hydrography, United States Coast Survey.

Professor BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

No. 1.—*Exposure of anchorages in Provincetown Harbor.*

CENTRAL POSITION.					MOST SHELTERED POSITION.				
Direction, true.	Fetch of the sea.	Distance of highland.	Angle of elevation.	Remarks.	Direction, true.	Fetch of the sea.	Distance of highland.	Angle of elevation.	Remarks.
	Naut. miles.	*Naut. miles.*	° ′			*Naut. miles.*	*Naut. miles.*	° ′	
N	0.71	1.40	0 28		N	1.30	1.88	0 22	From this "Most sheltered position" Long Point light bears north 67° 40′ east distant 0.53 nautical mile.
N.N.E	0.96	1.61	0 27		N.N.E	1.84	2.26	0 22	
N.E	1.48	2.31	0 1[illegible]		N.E	1.66	3.07	0 07	
E.N.E	2.26	3.55	0 5		E.N.E	0.38	3.23	0 12	
E	3.03	3.28	0 13		E	0.24	0.34	0 09	
E.S.E	4.39	4.63	0 09		E.S.E	0.18	0.27	0 16	
S.E	0.50	0.56	0 03	Max. exposure, 5.75 miles.	S.E	0.14	0.27	0 16	
S.S.E	0.58	0.67	0 05		S.S.E	0.12	0.29	0 19	
S	0.70	0.70	0 08	From this "Central position" Long Point Light bears south 36° east (true), and is distant 0.62 nautical mile.	S	0.08	0.37	0 15	
S.S.W	0.59	1.13	0 07		S.S.W	0.08	0.39	0 17	
S.W	0.54	0.97	0 02		S.W	0.10	0.70	0 09	
W.S.W	0.50	1.51	0 03		W.S.W	0.12	0.90	0 06	
W	0.53	1.18	0 37		W	0.16	1.24	0 04	
W.N.W	0.54	0.97	0 29		W.N.W	0.22	1.29	0 19	
N.W	0.56	1.02	0 27		N.W	0.36	0.97	0 41	
N.N.W	0.63	1.34	0 33		N.N.W	0.98	1.40	0 20	

No. 2.—*Exposure of anchorages in Vineyard Haven.*

CENTRAL POSITION.					MOST SHELTERED POSITION.				
Direction, true.	Fetch of the sea.	Distance of highland.	Angle of elevation.	Remarks.	Direction, true.	Fetch of the sea.	Distance of highland.	Angle of elevation.	Remarks.
	Naut. miles.	*Naut. miles.*	° ′			*Naut. miles.*	*Naut. miles.*	° ′	
N	4.43	7.50	0 15	From this "Central position" West Chop light bears north 42¼° west, and Holmes Hole spire south 42° west (true).	N	5.10	8.00	0 14	From this "Most sheltered position" Bug light-house bears south 27° west, and Old Wind Mill west 7° north (true).
N.N.E	5.15	15.00	0 09		N.N.E	5.89	15.50	0 09	
N.E	11.43				N.E	12.28			
E.N.E	29.21				E.N.E	0.54	0.82	0 34	
N. 79° E	Open to Atlantic.				E	0.28	1.03	0 32	
N. 82¼° E					E.S.E	0.17	1.03	0 35	
E	0.61	0.87	0 38		S.E	0.14	0.90	0 43	
E.S.E	0.47	0.62	0 45		S.S.E	0.14	0.36	1 02	
S.E	0.44	0.57	0 49		S	0.16	0.46	0 24	
S.S.E	0.47	0.62	0 27		S.S.W	0.21	0.70	0 31	
S	0.61	1.80	0 23		S.W	0.40	0.65	1 08	
S.S.W	0.90	1.64	0 24		W.S.W	0.38	0.65	1 16	
S.W	0.98	1.47	0 45		W	0.35	0.52	1 25	
W.S.W	0.60	0.98	0 34		W.N.W	0.34	0.39	1 54	
W	0.44	0.46	1 13		N.W	0.38	0.73	0 45	
W.N.W	0.52	0.52	0 32		N.N.W	0.51	0.65	0 51	
N.W	0.63	0.90	0 25						
N.N.W	4.52	5.50	0 15						

No. 3.—*Exposure of anchorages in Great Woods Hole.*

CENTRAL POSITION.			MOST SHELTERED POSITION.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N	0.16	From this "Central position" the southern point of Parker's Neck bears southeast (true), and is distant 0.6 nautical mile.	N	0.10	From this "Most sheltered position" Yellow House bears north 77° 30′ east (true), and is distant 0.23 nautical mile.
N. N. E	0.16		N. N. E	0.10	
N. E	0.18		N. E	0.10	
E. N. E	0.16		E. N. E	0.15	
E	0.25		E	0.20	
E. S. E	0.37		E. S. E	0.35	
S. E	0.58		S. E	0.70	
S. S. E	4.00		S. S. E	4.00	
S	0.48		S	0.55	
S. S. W	0.20		S. S. W	0.15	
S. W	0.18		S. W	0.30	
W. S. W	0.14		W. S. W	0.25	
W	0.23		W	0.25	
W. N. W	0.33		W. N. W	0.25	
N. W	0.34		N. W	0.20	
N. N. W	0.23		N. N. W	0.10	

No. 4.—*Exposure of anchorages in Tarpaulin Cove.*

CENTRAL POSITION.		
Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.	
N	0.37	From this "Central position" Tarpaulin Cove light bears south 49° 40′ west (true), and is distant 0.38 nautical mile.
N. N. E	0.30	
N. E	0.42	
E. N. E	12.20	
N. 82° 30′ E. to N. 85° E.	Open.	
E	5.77	
E. S. E	4.00	
S. E	3.28	
S. S. E	4.25	
S	5.90	
S. S. W	7.57	
S. W	0.34	
W. S. W	0.30	
W	0.39	
W. N. W	0.40	
N. W	0.40	
N. N. W	0.30	

No. 5.—*Exposure of anchorages in Edgartown Roadstead.*

CENTRAL POSITION.			MOST SHELTERED POSITION.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N	9.10	From this "Central position" Edgartown light-house bears south 55° 38′ west (true), and is distant 0.65 nautical mile.	N	9.49	From this "Most sheltered position" Edgartown light bears west 48° 55′ north (true), and is distant 0.41 nautical mile.
N. N. E	13.71		N. N. E	14.12	
N. E	1.26		N. E	1.47	
E. N. E	0.87		E. N. E	0.77	
E	0.97		E	0.47	
E. S. E	0.09		E. S. E	0.28	
S. E	0.62		S. E	0.19	
S. S. E	0.70		S. S. E	0.14	
S	0.78		S	0.13	
S. S. W	0.82		S. S. W	0.11	
S. W	0.84		S. W	0.13	
W. S. W	0.65		W. S. W	0.16	
W	0.63		W	0.25	
W. N. W	0.80		W. N. W	0.64	
N. W	3.81		N. W	0.53	
N. N. W	9.47		N. N. W	9.81	

No. 6.—*Exposure of anchorages in Old Stage Harbor.*

CENTRAL POSITION.			MOST SHELTERED POSITION.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N	1.45	From this "Central position" Chatham south light bears north 64° 20′ east (true), and is distant 3.68 nautical miles.	N	0.60	From this "Most sheltered position" Chatham south light bears north 67° east (true), and is distant 2.30 nautical miles.
N. N. E	1.73		N. N. E	0.50	
N. E	1.80		N. E	0.42	
E. N. E	1.95		E. N. E	0.40	
E	1.90		E	0.60	
E. S. E	1.65		E. S. E	1.44	
S. E	2.45		S. E	0.93	
S. S. E	3.80		S. S. E	1.26	
S	16.20		S	4.75	
S. S. W	23.35		S. S. W	23.20	
S. 38° W. to S. 48° 30′ W.	Open.		S. 38° 30′ W. to S. 48° 30′ W.	Open.	
W. S. W	28.15		W. S. W	29.17	
W	7.55		W	5.35	
W. N. W	2.85		W. N. W	1.64	
N. W	1.73		N. W	1.20	
N. N. W	1.35		N. N. W	1.85	

No. 7.—*Exposure of anchorages in New Bedford Harbor and Quick's Hole.*

NEW BEDFORD.			QUICK'S HOLE.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N.	1.81	From this "Central position" light north of Palmer's Island bears west 64° 40′ north; Clark's Point light bears south 65° west (true).	N.	9.14	From this "Central position" north point of Nashawena Island bears west 45° 20′ north (true), and is distant 0.65 nautical mile.
N. N. E.	1.95		N. N. E.	0.70	
N. E.	1.40		N. E.	0.40	
E. N. E.	1.29		E. N. E.	0.40	
E.	1.15		E.	0.45	
E. S. E.	1.63		E. S. E.	6.05	
S. E.	8.73		S. E.	5.90	
S. S. E.	9.05		S. S. E.	5.68	
S.	9.70		E. 86° S. to S. 6° W.	Open.	
S. 14° W. to S. 25° 30′ W.	Open.		S. S. W.	0.40	
S. W.	2.90		S. W.	0.40	
W. S. W.	1.95		W. S. W.	0.42	
W.	0.55		W.	0.40	
W. N. W.	0.53		W. N. W.	0.40	
N. W.	0.84		N. W.	0.55	
N. N. W.	3.55		N. N. W.	9.57	

No. 8.—*Exposure of anchorages in Plymouth Harbor.*

CENTRAL POSITION.			MOST SHELTERED POSITION.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N.	0.89	From this "Central position" beacon on pier-head bears south (true), and is distant 0.55 nautical mile.	N.	0.48	From this "Most sheltered position" beacon on pier-head bears south 12° 20′ west (true), and is distant 1.45 nautical miles.
N. N. E.	2.02		N. N. E.	0.61	
N. E.	0.51		N. E.	0.49	
E. N. E.	0.70		E. N. E.	0.36	
E.	25.20		E.	0.59	
E. S. E.	26.00		E. S. E.	0.27	
S. E.	0.63		S. E.	0.30	
S. S. E.	0.94		S. S. E.	0.37	
S.	0.53		S.	1.66	
S. S. W.	0.52		S. S. W.	2.23	
S. W.	0.46		S. W.	1.31	
W. S. W.	0.41		W. S. W.	0.64	
W.	0.55		W.	0.29	
W. N. W.	0.49		W. N. W.	0.23	
N. W.	0.58		N. W.	0.35	
N. N. W.	0.72		N. N. W.	0.50	

No. 9.—*Exposure of anchorages in Boston Harbor.*

NANTASKET ROADS.			NANTASKET ROADS.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N	1.03	From this "Central position" sunken beacon bears south 55° 15′ west; Long Island light bears west 47° 50′ north (true).	N	0.59	From this "Central position" sunken beacon bears south 59° 40′ west (true), and is distant 0.58 nautical mile.
N. N. E	0.36		N. N. E	1.59	
N. E	1.07		N. E	1.29	
N. 63° 30′ E. to N. 85° E.	Open.		N. 61° 15′ E. to N. 72° E.	Open.	
E	1.05		E	0.59	
E. S. E	0.62		E. S. E	0.65	
S. E	0.62		S. E	0.62	
S. S. E	2.90		S. S. E	0.62	
S	0.42		S	0.55	
S. S. W	1.10		S. S. W	2.13	
S. W	3.10		S. W	2.26	
W. S. W	3.74		W. S. W	2.87	
W	1.82		W	2.09	
W. N. W	1.52		W. N. W	1.31	
N. W	1.42		N. W	1.00	
N. N. W	0.92		N. N. W	1.35	

No. 10.—*Exposure of anchorages in Boston Harbor.*

HULL BAY.		
Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.	
N	0.75	From this "Central position" Steamboat House bears north (true), and is distant 0.77 nautical mile.
N. N. E	0.65	
N. E	0.78	
E. N. E	1.62	
E	1.62	
E. S. E	1.67	
S. E	2.71	
S. S. E	1.68	
S	1.15	
S. S. W	2.12	
S. W	1.82	
W. S. W	1.65	
W	0.72	
W. N. W	0.70	
N. W	0.57	
N. N. W	2.20	

No. 11.—*Exposure of anchorages in Boston Harbor.*

PRESIDENT ROADS.			GEORGE'S ROADS.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N	1.03	From this "Central position" Long Island light bears east 36° 20′ south (true); flag-staff on Deer Island bears north 49° 40′ east.	N	1.98	From this "Central position" Long Island light bears west 63° 20′ north (true); Fort Warren flag-staff bears north 89° 05′ east.
N. N. E	0.83		N. N. E	0.67	
N. E	0.78		N. E	0.42	
E. N. E	0.79		E. N. E	1.02	
E	0.83		E	0.78	
E. S. E	1.38		E. S. E	1.70	
S. E	0.92		S. E	3.15	
S. S. E	1.01		S. S. E	1.47	
S	1.63		S	1.67	
S. S. W	1.16		S. S. W	0.42	
S. W	1.01		S. W	3.53	
W. S. W	2.82		W. S. W	0.82	
W	2.35		W	0.65	
W. N. W	1.35		W. N. W	0.52	
N. W	1.00		N. W	0.56	
N. N. W	1.58		N. N. W	0.54	

No. 12.—*Exposure of anchorages in Marblehead Harbor.*

CENTRAL POSITION.			MOST SHELTERED POSITION.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N	0.30	From this "Central position" Fort Sewall bears north; Marblehead light bears north 64° east (true).	N	0.30	From this "Most sheltered position" Fort Sewall bears north 24° east; Marblehead light bears north 53° 40′ east (true).
N. N. E	3.60		N. N. E	0.70	
N. E	6.00		N. E	6.00	
E. N. E	0.35		E. N. E	0.20	
E	0.25		E	0.20	
E. S. E	0.20		E. S. E	0.20	
S. E	0.20		S. E	0.20	
S. S. E	0.20		S. S. E	0.30	
S	0.20		S	0.30	
S. S. W	0.70		S. S. W	0.35	
S. W	0.75		S. W	0.35	
W. S. W	0.50		W. S. W	0.20	
W	0.30		W	0.20	
W. N. W	0.20		W. N. W	0.10	
N. W	0.22		N. W	0.10	
N. N. W	0.30		N. N. W	0.30	

No. 13.—*Exposure of anchorages at Salem Harbor.*

CENTRAL POSITION.			MOST SHELTERED POSITION.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N............	0.75	From this "Central position" Baker's Island light-house bears east 5° 20′ south (true); Marblehead light-house bears south 7° west (true).	N............	0.40	From this "Most sheltered position" Fort Pickering bears north 20° 40′ east (true), distant 0.50 nautical mile.
N. N. E.......	0.90		N. N. E.......	0.50	
N. E..........	2.00		N. E..........	2.90	
E. N. E.......	1.25		E. N. E.......	8.00	
E............	Open.		E............	0.30	
E. S. E.......	Open.		E. S. E.......	0.30	
S. E..........	Open.		S. E..........	0.30	
S. S. E.......	1.80		S. S. E.......	0.40	
S............	15.00		S............	0.60	
S. S. W.......	1.45		S. S. W.......	1.10	
S. W..........	1.50		S. W..........	0.90	
W. S. W......	1.90		W. S. W......	0.90	
W............	2.30		W............	0.60	
W. N. W......	1.30		W. N. W......	0.50	
N. W.........	0.85		N. W.........	0.40	
N. N. W......	0.70		N. N. W......	0.40	

No. 14.—*Exposure of anchorages at Gloucester Harbor.*

CENTRAL POSITION.			MOST SHELTERED POSITION.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N............	0.90	From this "Central position" light-house on Ten Pound Island bears north 27° 20′ east; light-house on Eastern Point bears east 72° south (true).	N............	0.24	From this "Most sheltered position" beacon on Five Pound Island bears north 1° 40′ east (true), and is distant 1.62 nautical miles.
N. N. E.......	0.90		N. N. E.......	0.18	
N. E..........	0.75		N. E..........	0.37	
E. N. E.......	0.62		E. N. E.......	0.18	
E............	0.70		E............	0.10	
E. S. E.......	0.50		E. S. E.......	0.12	
S. E..........	0.45		S. E..........	0.20	
S. S. E.......	0.65		S. S. E.......	0.18	
S............	28.50		S............	0.10	
S. S. W.......	20.00		S. S. W.......	0.10	
S. W..........	18.60		S. W..........	0.21	
W. S. W......	0.70		W. S. W......	1.00	
W............	0.49		W............	0.17	
W. N. W......	0.62		W. N. W......	0.15	
N. W.........	0.68		N. W.........	0.19	
N. N. W......	0.70		N. N. W......	0.23	

No. 15.—*Exposure of anchorages in Lower Bay, New York Harbor.*

CENTRAL POSITION.			MOST SHELTERED POSITION.		
Direction, true.	Fetch of the sea.	Remarks.	Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.			*Naut. miles.*	
N	5.12	From this "Central position" East beacon bears east 24° south; Bayside beacon bears south 36° 40′ west (true).	N	8.64	From this "Most sheltered position" East beacon bears north 60° 40′ east; Conover beacon bears south 25° 30′ west, (true).
N. N. E	7.13		N. N. E	7.24	
N. E	7.70		N. E	8.55	
E. N. E	14.95		E. N. E	0.95	
N. 78° E. to E. 22° S.	Open.		E	1.00	
E. S. E	3.42		E. S. E	1.20	
S. E	5.27		S. E	3.50	
S. S. E	5.20		S. S. E	2.90	
S	3.57		S	2.70	
S. S. W	3.35		S. S. W	2.82	
S. W	3.50		S. W	3.30	
W. S. W	6.98		W. S. W	10.05	
W	7.67		W	10.60	
W. N. W	4.55		W. N. W	8.05	
N. W	3.37		N. W	6.22	
N. N. W	3.73		N. N. W	7.05	

No. 16.—*Exposure of anchorages in Upper Bay, New York Harbor.*

CENTRAL POSITION.		
Direction, true.	Fetch of the sea.	Remarks.
	Naut. miles.	
N	2.15	From this "Central position" flagstaff on Bedloe's Island bears north 1° 41′ west (true); Robbins's Reef light bears south 55° 20′ west.
N. N. E	3.77	
N. E	1.70	
E. N. E	1.25	
E	2.07	
E. S. E	1.82	
S. E	1.50	
S. S. E	1.75	
S	15.17	
S. S. W	3.20	
S. W	2.02	
W. S. W	2.25	
W	2.95	
W. N. W	2.45	
N. W	2.27	
N. N. W	2.28	

No. 17.—*Anchorage-room and average exposure.*

Name of port.	Number of vessels. Men-of-war.	Merchant-ships.	Miscellaneous merchant-vessels.	Outer limits.	Fetch of the sea in nautical miles for different quadrants. N. E.	N. W.	S. W.	S. E.	Remarks.
Provincetown	12	85	246	Line from Long Point to west end of State Dike.	1. 64	0. 58	0. 56	1. 83	1st position of table No. 1.
Vineyard Haven	3	60	174	Line from East to West Chop.	Open..	2. 02	0. 76	0. 49	1st position of table No. 2.
Woods Hole	0	7	18	Line from end of Parker's Neck to Bluff Island.	0. 17	0. 27	0. 22	1. 33	1st position of table No. 3.
Tarpaulin Cove	0	0	10	Chord	Open..	0. 36	2. 83	4. 34	Table 4.
Edgartown Roadstead	22	61	189	Line from Eel Point to Cape Poge.	5. 21	4. 73	0. 75	0. 72	1st position of table No. 5.
Plymouth	11	78	227	Gurnet Light	4. 06	0. 62	0. 48	10. 10	1st position of table No. 8.
BOSTON HARBOR.									
Nantasket Roads	36	241	473		2 points open.	1. 32	2. 26	1. 21	1st position of table No. 9 is assumed to represent the average.
George's Roads	4	78	231		0. 87	0. 73	1. 48	1. 89	
Hull Basin	12	106	376		1. 05	1. 05	1. 63	1. 86	Table No. 10.
President Roads	21	191	563		0. 83	1. 40	1. 74	1. 13	Table No. 11.
Governor's Island to city bridges	1	56	184						Sheltered.
Boston Harbor, total	74	672	1, 827						
Marblehead	3	17	49	Chord	2. 55	0. 25	0. 55	0. 20	1st position of table No. 12.
Salem	62	275	800	Line connecting Gerry's Island, Eagle Island, and Little Misery.	Open..	1. 09	3. 37	Open.	Roadstead, 1st position of table 13.
Gloucester	0	4	25	Fort Point	0. 22	0. 19	0. 36	0. 15	2d position of table No. 14.
Gloucester Roadstead	29	120	327	From Fort Point to Norman's Woe Rock.	0. 76	0. 67	13. 44	4. 05	1st position of table No. 14.
Gardiner's Bay and tributary basin	1, 041	4, 935	13, 098	Gardiner's Island					Numerous sheltered basins.
New York, lower harbor	260	2, 324	6, 740	Sandy Hook and Narrows	Open..	4. 51	4. 86	Open.	Open 3 points; see 1st position of table No. 15.
New York, upper harbor	307	1, 406	4, 225	Narrows to Spuyten Duyvel Creek.	2. 20	2. 38	4. 13	3. 42	Table No. 16.
New York Harbor, total	567	3, 730	10, 965						

NOTE.—It is premised that a man-of-war requires 23 feet depth at the anchorage and its entrance, and that all merchant-vessels require 18 feet at low water.

REPORT ON PHYSICAL SURVEYS MADE AT MARTHA'S VINEYARD AND NANTUCKET, DURING THE SUMMER OF 1871, BY HENRY MITCHELL, CHIEF IN PHYSICAL HYDROGRAPHY, UNITED STATES COAST SURVEY.

DEAR SIR: In response to a call from the Massachusetts Board of Harbor Commissioners, you directed me to extend my project for the season so as to cover, as closely as required, the harbors of Edgartown, Vineyard Haven, and Nantucket, with their approaches by sound and sea.

Presuming that the Board I have referred to will be supplied with such portions of this report as may be deemed useful in considering the petitions for improvements which have come in from said localities, I shall arrange my notes in three brief sections, without reference to the actual order in which we have pursued the inquiries. I shall first give a limited resumé of the physical aspect and peculiarities of the neighborhood; then, from a strictly practical point of view, recount the results we have reached, and make such suggestions as these results seem to warrant; and, finally, furnish in the usual form the elements of the field-work.

§ 1. PHYSICAL ASPECT AND PECULIARITIES.

A glance at the map of New England reveals in the general direction of the valleys, ponds, harbors, bays, and sounds, the traces of great forces moving from the north and east—forces which controlled, or developed themselves in, the movements of the glaciers, and ceased to operate, perhaps, before the present agencies of change existed. If we descend from the general features to the study of details, we discover that the drift of the glacial period has been washed down from the hills by the rain, torn from the headlands by the waves, and strewn along by the sea, so that original depressions are being filled up and new features appearing, which we easily recognize as the result of natural operations now in progress.

Upon the islands of Martha's Vineyard and Nantucket, where the depressions are generally transverse to the trend of the coast, barriers of sand have been thrown across them at the sea-margins, both upon the north shore and upon the south, but more conspicuously on the latter, which is more exposed to the storm-waves of the ocean. One may recognize the strip of beach that crosses the lagoon of Vineyard Haven as the same kind of "*littoral cordon*" as the ridges of sand that cut off Tisbury and other ponds from the ocean, and Chappaquiddick Neck, at the entrance to Edgartown, differs from Cotamy Beach only in its exposure. The main entrance to Edgartown from the north can only have been maintained by the tidal circulation, and the southern opening closed simply because the circulation was unequal to the task of resisting the constructive efforts of the waves. That there was once an open passage-way from the sound to the ocean through this harbor can scarcely be doubted, for the bluffs on either hand bear witness to the wear of seas to which under the present circumstances they can never be subjected.

It is probable that Cotamy Bay immediately after the melting of the glaciers was an open fiörd; that the sand driving along shore from the westward converted the fiörd into a bight, and the bight into a lagoon.

The history of Greytown Harbor, Nicaragua, which I had the opportunity to study while a member of the committee of the National Academy appointed to investigate it, furnished a similar order of changes, shown by comparative surveys. In this instance a cove became successively a bight and a lagoon, by the advance of a sand-drift across its mouth. When the sands had nearly crossed, the opening took the form of an inlet, with a depression at the pass, and a bar outside. This inlet struggled for existence, but finally closed. The ponds on the south sides of Martha's Vineyard and Nantucket have all, perhaps, been little fiörds, which have been shut up by the coast-sands. The difference, however, between Cotamy Bay and the other sand-barred fiörds is very great when we consider that with two openings a great tidal circulation is possible. I cannot altogether agree with Professor Whiting in supposing that the beach has gone on accumulating till it presents a barrier difficult to overcome, because the power of the tidal circulation seems to me out of all proportion to the obstacle. I incline rather to the impression that the outlet, shifting to the eastward, has, in this instance, happened to run its course and close on the border of Muskeget

Channel before any great storm has occurred to open a new pass to the westward. It will be seen, from what I shall say hereafter, that the opening must gradually lose its strong tidal current as it moves eastward, and very decidedly when it reaches Muskeget Channel, where the contrasts of tidal elevations within and without diminish.

Professor Whiting's repeated topographical surveys along the south side of Martha's Vineyard show that the bluffs are being continually undermined by the sea, and since the waves, running before the prevailing westerly winds, strike the shore diagonally, there is a tendency of all materials to work down to the eastward, a tendency which seems to have resulted in the choking up of all the indentations of the original shore-line, and finally in the formation of shoals on the border of Muskeget Channel, where the coastwise movement is turned off by the great stream from the sound. I have no doubt that Wasque Shoal has received supplies from the entire length of the south shore of the island, although in the main, perhaps, it is a product of the wear of the east shore of Chappaquiddick. This shoal, like the False Hook at the entrance to New York, lies in the debatable district between opposing movements of the sea.

In many respects the openings through Cotamy Beach, in location and history, have resembled those through Sandy Hook at Navesink Highlands, known as the Shrewsbury Inlets. In both places the shifting has been induced by a diagonal set of the waves, and in both places the openings, after long travel, have been prone to close in particular neighborhoods, where they have been compelled to halt and make a struggle for existence.

The material which falls from the headlands into the sea is not borne far off, but continually crowded toward the shore. As the waves drive up the beach, great masses of sand and stones are forced on shore, but the reacting "under-tow" carries back always a portion of the finer material. By the grinding action of the breaker, and the selecting operation of the under-tow, the strand becomes largely composed of fine sands, easily caught up by the dry winds, and formed into dunes, or *galls*, as they are properly called, upon Nantucket. The sea in its onset is *constructive* up to a certain elevation. It seems disposed everywhere to preserve a dike, but this barrier, unless augmented by wind-borne material, never exceeds a certain limit. It does not restrain the over-leaping sea in the fury of the storm, but limits its peaceful domain.

The most casual observer may distinguish in Cotamy Beach a contrast of appearance between the *wind-worn* and *water-worn* districts; the former characterized by irregular mounds, the latter by smooth surfaces, declining in either direction from a crest-line to the sea; in the one case the contours are apparently groups of concentric curves, in the other parallel straight lines. In the profiles of different cross-sections, the two forms of beach are still more distinctly shown, so that in most cases we can positively assert that *this* is a *dune* section where the wind arranges, and *that* a *natural dike*, still washed by the storm-seas. There are, it is true, some sections where the wind and the sea have both left traces of their struggle for supremacy, but these present little confusion to the careful observer, who easily distinguishes the traces of the water from those of the wind.

The wind plays its part upon a stage previously raised by the water, and builds higher still. The coarse grasses which take root in the dunes arrest the flying sands still more effectually, and with them the fertilizing dust of the shore. In this way the levee thrown up by the sea is gradually strengthened, till it becomes a permanent barrier against the storm.

Where exposed to the open ocean, the levee maintained by the sea is seven to eight feet above ordinary high water; in bays and sounds, where somewhat sheltered, it is less. Of course storm-seas easily pour over it, and these, by sweeping the sands from front to rear, cause the levee to move back without changing its form usually. The movement is like that of a dune, but the slopes maintained are the reverse.

The island of Nantucket is mainly a heap of glacial drift. Except a very remarkable bank of oyster-shells, which crops out from Sankaty Head, about sixty feet below the brow of the cliff, no ante-glacial deposit is found. Mr. Edward C. Cabot, when attached to the Coast Survey party of Lieutenant Charles H. Davis, first called attention to this exceptional feature, and he ascertained that this bank was met with in digging wells in the interior of the island. It would be very interesting to explore this deposit, as you have encouraged me to do, and to ascertain if it is a shell levee, like those I have seen upon the shores of the Bahama Islands. If it is, its *strike*, and the relations of its two slopes, would reveal the whereabouts of the ocean, and perhaps the height of its waves in those ante-glacial ages.

Great Point, Coatue, and the larger part of Smith's Point, are modern formations, and composed, probably, of material torn by the waves from the seaward side of the island. In the midst of the town is a long bluff, where the drift-deposit has been undermined by the sea, probably before the shelter offered by Great Point and Coatue existed. I refer here to the "Bank" between Orange and Union streets, and its continuation in the quarter known as the *North Shore*. These ancient headlands are now covered with houses, and their slopes grown over with grass. The Haulover, which it is proposed to cut through, connects the drift-mound known as Coskata with the main body of the island, and separates the Upper Harbor from the ocean. It has always been a portage for fishing-boats, as its name implies, and is nearly of the same form and area upon the maps of Des Barres, 1776; William Mitchell, 1838; Coast Survey, 1846; and Dr. Ferdinand C. Ewer, 1869, all of which represent actual surveys. The section given upon our sketch is the mean of three lines of levels, following depressions from the harbor, on the one side, to the ocean on the other. The distance from rear to front is unusually short, yet still I claim that the form is that of a sea-built dike. But even if this barrier be, as Mr. Joseph B. Macy and others at Nantucket assume from their examinations, a remaining strip of the original *drift*, we might still expect its exposed portion to wear the form impressed upon it by the sea; so that I do not give much weight to my own view, which is *literally* superficial, as yet.

In the natural formation of an opening through the *littoral cordon* of the coast, the waves play only a preliminary part; *it is the current which digs the channel.* The overleaping waves weaken the dike, but it is by filling the basin behind to overflowing that the breach is opened wide and deep.

In cases like Chatham, where the length of exposed beach is in very great ratio to the area of the basin, the latter is very liable to overflow, and inlets are the frequent products of great storms. The Haulover Beach, on the contrary, is so short from Coskata to Squam that it does not admit many over-leaping seas, and therefore the basin within never, perhaps, swells to overflowing.* The experiment proposed is, therefore, one which nature may never have tried.

The distinguishing peculiarity of the district under examination is its unparalleled tidal currents. Nantucket was called by the Northmen "Straumey," (Stream Island,) and the sound "*Straumfiörd.*"†

There is no other part of the world, perhaps, where tides of such very small rise and fall are accompanied by such strong currents running far out to sea. The navigator, approaching the coast, scarcely makes a land-fall before he finds his ship "moved onward from beneath," and the same wonder fills him now that first, perhaps, so long ago "mingled strangely with the fears" of those ancient mariners.

There approach our coast from the ocean two oscillations of the tide, which meet, or (as you express it) "*form their node*," southward of Nantucket Island. From Great Point, Nantucket, all along the outer coast of America to the northward, high water occurs at, or shortly before, the transit of the moon; while from Smith's Point, Nantucket, along the outer coast to the southward, high water occurs four or five hours earlier. "*South moon makes high water*" and "*South-east moon makes high water*," are the sailors' rules respectively applied to the two divisions of the coast we have named.

My very close observations made in 1854 showed that the nodal-line intersects the shore-line of Nantucket between the meridians of 70° 0′ and 70° 5′, *i. e.*, a short distance to the westward of the shoals. These two oscillations, entering the sound, the one by Gay Head and by Muskeget Channel, and the other by the Eastern Entrance, give very complicated tides between Tarpaulin Cove and Tuckernuck.

In the small tides of Holmes' Hole, Muskeget Channel, and Weweeder, (south side of

* I follow the spelling of the Indian names given upon the valuable map of Dr. Ewer.

† I infer that the island discovered in 1007 by Thorfinn the Hopeful, "*past which there ran strong currents, which was also the case farther up the fiörd,*" must have been Nantucket. Most of the commentators of the *Sagas* award the discovery of the south shore of New England to Lief, the son of Eric, but his mention of "*much land left bare by the tide*" is fatal to this interpretation of his account. Vinland, as seen by Leif, must have lain northward of Cape Cod. The palm for first entry upon our field of inquiry belongs to Hopeful Thorfinn.

Curiosity has led me to consult Wheaton's Northmen, the Antiquitates Americanæ, and some MS. kindly sent to me by F. S. Stallknecht, member of the Royal Society of Antiquaries at Copenhagen.

Nantucket,) there are sometimes four "high tides" in one day distinctly given by gauging. But I must not enter upon details that would but complicate the conception; and I would remark, by way of preparing the reader to trust my calculations given below, that the phenomena present really no complications, when simultaneously observed from point to point.

§ 2. EDGARTOWN.

Upon the map which accompanies this report, I have drawn profiles of the tidal curves for Cotamy, inside and outside, so that one with his eye may see how sharp the contrasts of the tides appear on the two sides of this beach, and how much the relative levels differ. Not trusting any single day's work, however, but going back to the whole series, I give below a table of average conditions:

	Time.	
Cotamy Bay at the same level as the sea outside	$2^h\ 32^m$	Before moon's transit.
High water in Cotamy Bay	$0^h\ 28^m$	After moon's transit.
Greatest height in Cotamy Bay above the sea outside	$0^h\ 40^m$	After moon's transit.
Cotamy Bay again at same level as the sea outside	$4^h\ 40^m$	After moon's transit.

DIFFERENCE OF LEVEL.

	Feet.
Max. height of Cotamy Bay above the sea, (after the larger high water)	1.36
Max. height of Cotamy Bay above the sea outside during a N.E. gale of ordinary violence	1.83

The times of the preceding table, which are counted from the moon's transit, (*i. e.*, from her southing or northing,) are subject to variations of about forty minutes either way. It will be safe, however, to provide for throwing open the canal two hours before the time of transit given in the almanac.

Those differences of level only are given in our table which favor the outflow and those only which follow after the *larger* of the two tides which occur upon the same day. Care should be taken to select this larger tide, and this may be done by referring to the heights at Boston given in the tide-tables of the Coast Survey for every day in the year.

The differences of height do not increase very much from Neaps to Springs; but as the opening is to be made (according to our presumption) about the time of high water, there will be a saving of labor by selecting a period of high tides. There will also be a decided advantage in selecting a period of strong winds from north round to east, but winds from the opposite quadrant will prove very unfavorable. During the period when the surface of Cotamy Beach is above that of the ocean, *i. e.*, from $2^h\ 32^m$ before till $4^h\ 40^m$ after the transit, the current runs southward through Muskeget Channel, and sometimes feebly to the westward along the outside shore of Cotamy Bay, but the prevailing stream along this shore sets to the eastward within the Wasque Shoal.

The currents of Edgartown Harbor underwent an important change of regimen when the opening through the south beach closed. Lieutenant Davis's observations in 1847 showed that the stream commenced to run by the town to the *northward*, and out over the bar, two hours before low water, and that it continued to hold this direction till within two hours of high water. As things are now, the stream begins to run *in* over the bar, and *southward* past the town, about the time of low water, and, with a single halt at the fourth hour, continues to run in until near time of high water.

Under the old regimen, much more water flowed out to the northward than ever returned. A glance at the tidal curves upon our sketch will show how this happened. When the tide was low in Cotamy Bay, it was high on the outside, so that the inlet and the channel over the outside bar were broad and deep, admitting a great volume of water. On the other hand, when the bay was full, the tide outside was low, and the channels through the inlet and bar were much reduced. In my first attempt at anything like a scientific paper, over fifteen years ago, I called attention to the fact that "*about the same relation is preserved between the surfaces of the water at Brant Point and Weweeder as between Cape Poge and Wasque, and that all the advantages which the harbor of Edgartown possesses over that of Nantucket would seem to be due to the existence of a southern opening in the former case.*" I remember that this was based upon a comparison of levels which I had made from mere curiosity, and had no reference to any proposed improvement at either of these ports.*

* See Appendix No. 37, Annual Report of Coast Survey for 1856.

The soundings in the harbor of Edgartown given upon the accompanying chart, executed by Mr. Marindin, differ from those which appear upon the chart of Lieutenant Charles H. Davis, (dated 1846,) in three localities of limited extent.

1st. One foot more water can now be brought into the town basin over the bar.

2d. The apron of sand within Chappaquiddick Point has extended so as to reduce the depth all the way across the channel, and impair the holding-ground. The cross-section most encroached upon has lost about twenty per centum of its area.

3d. An increase of the bulkhead or shoal in the broadest portion of Cotamy Bay has occurred, and amounts to nearly one million of cubic yards.

From inquiry among the citizens of Edgartown, I learned that the increase of water over the bar had not been noticed by them, so I conclude that it may be nothing new, but a gradual change of past years. It was quite otherwise with the apron of Chappaquiddick Point, which had excited attention by its recent advances. The shoal in Cotamy Bay had undergone so many modifications of form within the memories of pilots and boatmen, that their testimony was uncertain. Until we can have still another survey, we must infer that the two years' closure of the beach has not affected the bar or bay, but has conduced to the shoaling of the main channel, and has greatly reduced its width at one point. What this change portends I do not dare predict, but I agree with the good people of Edgartown in thinking something ought to be done to stop it forthwith.

§ 3. Nantucket.

In the table which follows, I give the elements of the tides at stations occupied by my party in 1854.

Tide table for Nantucket, (averages from long series of observations.)

Localities.	High water occurs.		Low water occurs.		Rise and fall.	
	Before the moon souths.		After the moon souths.			
	h.	*m.*	*h.*	*m.*	*feet.*	
Smith's Point	4	38	1	31	2.24	Outside stations.
Weweeder	4	20	1	49	1.50	
Siasconset	0	44	5	20	2.10	
Great Point	0	18	5	36	3.44	
Tuckernuck	0	08	5	40	2.84	
	After the moon souths.					
Brant Point	0	13	6	03	3.07	
Commercial wharf	0	20	6	06	3.00	
Head of harbor	1	02	7	51	3.10	Inside of Haulover.

It will be observed that between Siasconset and Great Point the tides belong to the eastern system, but are not free from the admixture of the western system, which prevails as far as Weweeder. The tide of Nantucket Harbor also belongs to the eastern system, so that we have, on either side of the Haulover, modifications of the same tide-wave, and not distinct tidal systems, as at Cotamy on Martha's Vineyard. The delay, however, and the distortion of profile which the tide undergoes in its passage to the upper harbor, give rise to a considerable contrast of elevation on the two sides of the Haulover, amounting to over one foot at the time of maximum difference, an hour after the low water and two hours after the high water of the upper harbor. From the best that I can do with computations from stations so distant from the scene, I should say that from the time of high water (in the upper harbor) until within two hours and a half of low water, the surface of the upper harbor is above that of the ocean. For some little time before high water the stream would be continuous through the narrows into the upper harbor, and out through the inlet into the sea. The reverse would be true at low water. It will be very easy, from a few observations on either side of the Haulover, before the cut is made, to determine more exactly the relations upon which I now speak so timidly. By connecting the observations of a few days with the benches of my long series at other points, the proper moment for throwing open the communication may be predicted with certainty in terms of interval after the transit of the moon.

The movement into the basin from outside will exceed in velocity that which, six hours later, will obtain in the opposite direction; so that an interior accumulation of sand will be likely to occur as well as a bar outside. The basin of the upper harbor is, however, deeper than any other part of the port, and not now used for commercial purposes.

The coastwise currents are strong off Siasconset and also at Great Point, but off the Haulover they are feeble. Captain George W. Coffin, of Siasconset, made current observations for me along the east shore of the island in 1855, and it is to these that I refer.

There are few cases where a community have less to lose by the failure or more to gain by the success of an enterprise. The new passage-way would build up the fishing interests of the place; it would also be an avenue for pilots carrying hope and assistance to vessels bewildered among the shoals, and for life-boats bound on errands of mercy.

It is five and a half nautical miles from the Haulover to the north end of Bass Rip; it is over sixteen miles to the same point from the present opening of the harbor at Brant Point, following the shortest water-route inside of the Point Rip.

§ 4.—ELEMENTS OF THE FIELD-WORK.

In the harbors of Edgartown and Vineyard Haven there were executed 139 linear miles of soundings, containing a total of 20,547 casts of the lead; 2,016 angles were measured; 9 current and three tidal stations were occupied.

The current observations were taken at different depths whenever the station lay in the channel. The stations in the Sound were occupied with a view to determine causes of the remarkable shoal known as the Hedge Fence; but I am not satisfied that we fully understand this shoal yet, so I do not report upon it.

The bench of our survey at Edgartown is the outer edge of the *water-table*, (or set-off at top of stone foundation,) under the window on the right-hand side, on entering the front door of the Martha's Vineyard National Bank. Mean low water, as observed upon our gauge at town wharf, (about 500 feet distant,) is 15.16 feet below this bench, high water 13.16 feet, and the highest storm-tide of the last twenty years, (with wind E. S. E.,) 10.50. The storm-tide referred to was observed by Mr. Dunham, in November, 1871. It rose about two-tenths of a foot higher than a previous remarkable rise observed by him many years ago. The tide of Cotamy Bay, since the closing of the beach, has the same form as that at the town wharf, but occurs about a quarter of an hour later.

I have made two visits to Nantucket, in the first of which I procured the three sections of the Haulover, the mean of which appears upon our chart.

The second visit was fruitless, by reason of a snow-storm, which interrupted operations.

Before closing this report I ought to call your attention to the hydrography executed by my excellent assistant, H. L. Marindin, which is good. Acting under my advice, he did not cover the ground equally, but expended the most labor where most useful. The previous chart of Lieutenant (now Rear-Admiral) Davis, although made in the early days of our service, has furnished a secure base of comparison. Over a large part of the field the two surveys agree, and where this is not the case, the causes of change have been investigated, and close work executed.

Mr. F. H. North served as aid upon the work, and was engaged upon current and tides. Messrs. Lincoln, Cabot, and W. E. Sparrow, students of the Massachusetts Institute of Technology, and Mr. S. G. Pendleton, student at the Renssalaer Institute at Troy, lent their aid to us during the vacation, and did very good service with very good will.

Very respectfully submitted.

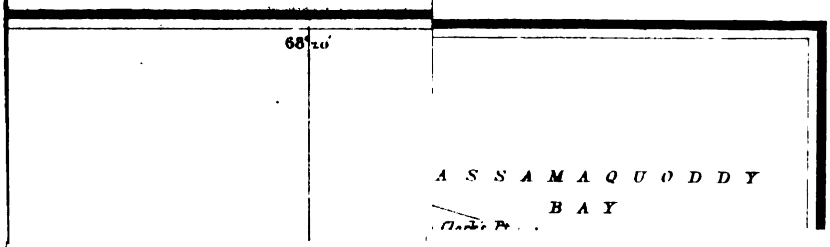
HENRY MITCHELL,
Coast Survey.

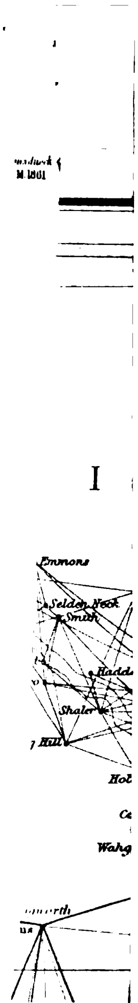
Professor BENJAMIN PEIRCE,
Superintendent United States Coast Survey.

LIST OF SKETCHES.

Sketch No. 9 will be published in report for 1870.

Sketch No. 27 having been destroyed in the late fire in Boston is omitted.

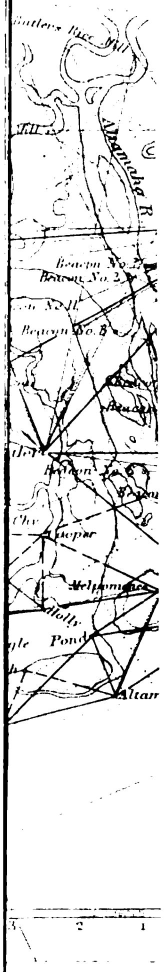

68°20′
ASSAMAQUODDY
BAY

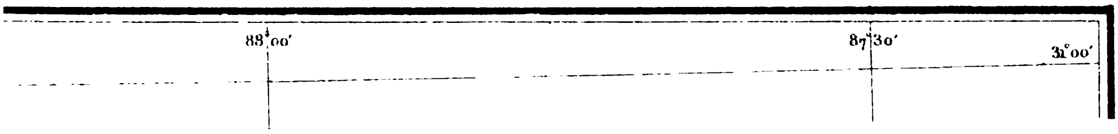

Emmons
Selden Neck
Smith
Shaler

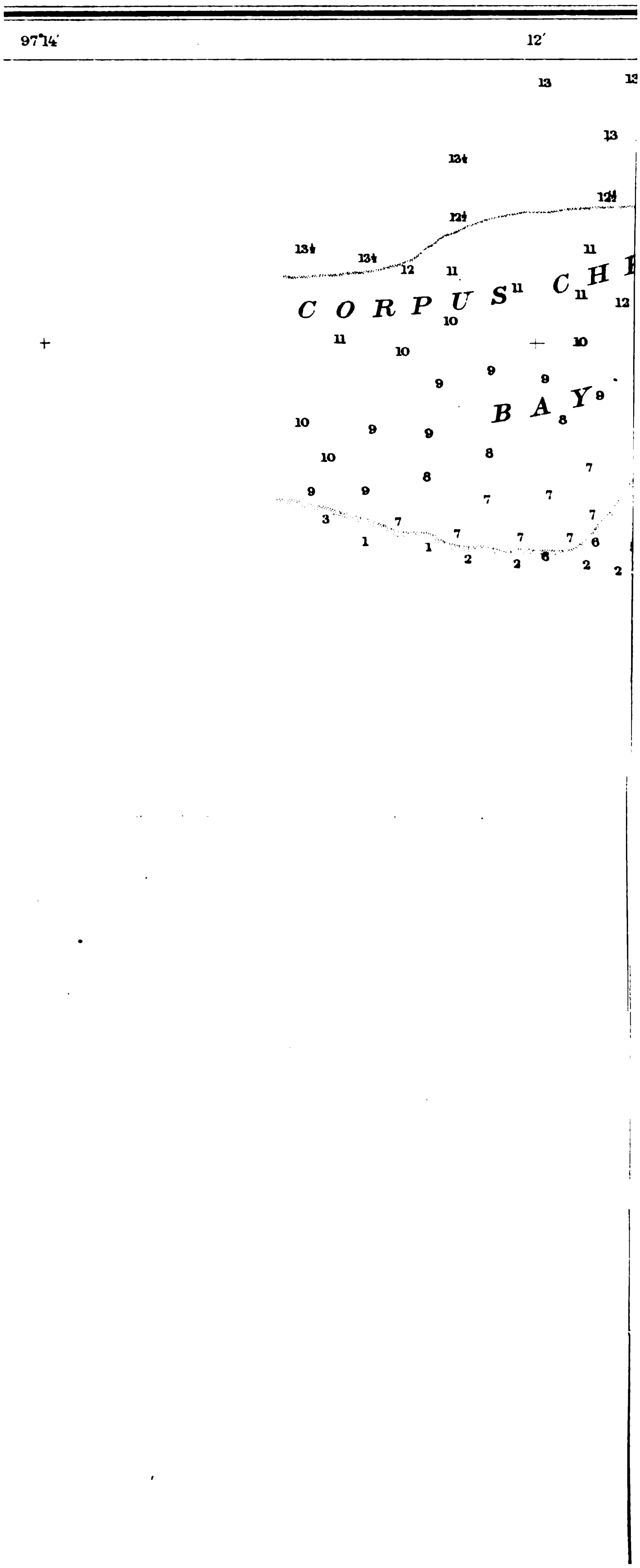
10

8

OSSA



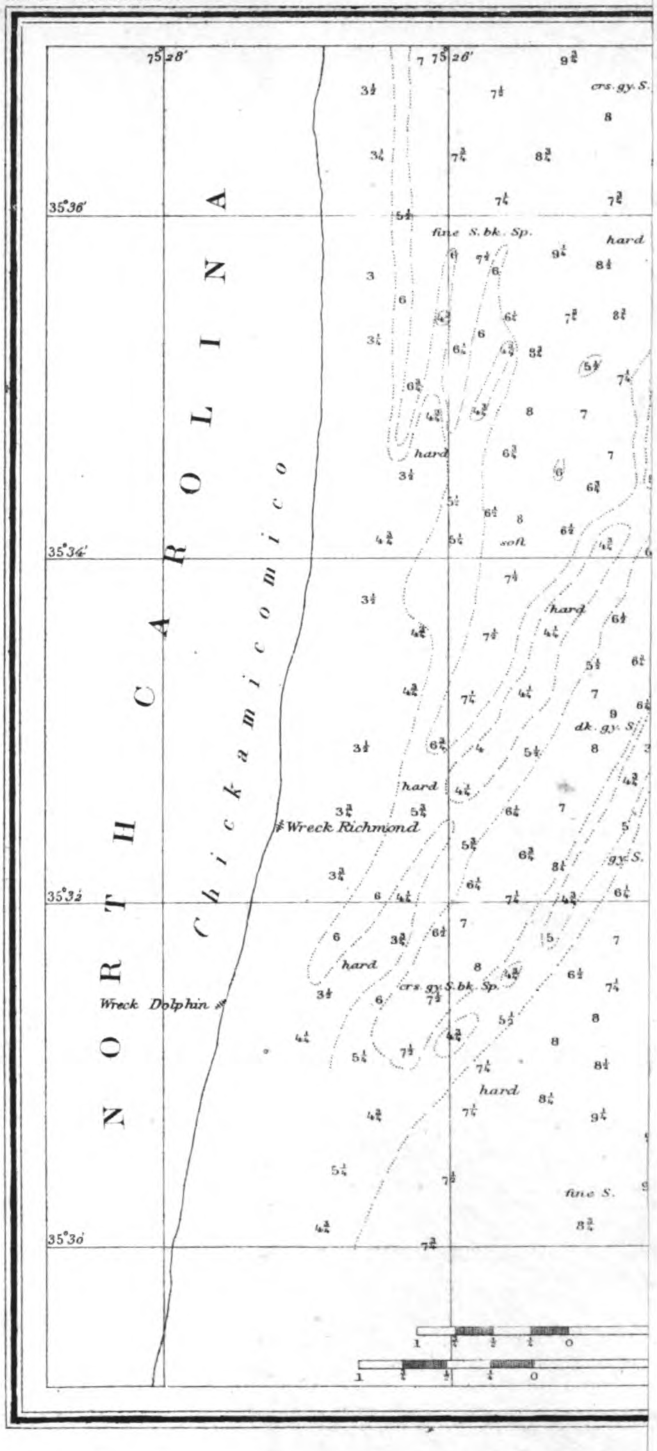

88°00'
87°30'
31°00'


97°14′
12′
C O R P U S C H
B A Y

14

16

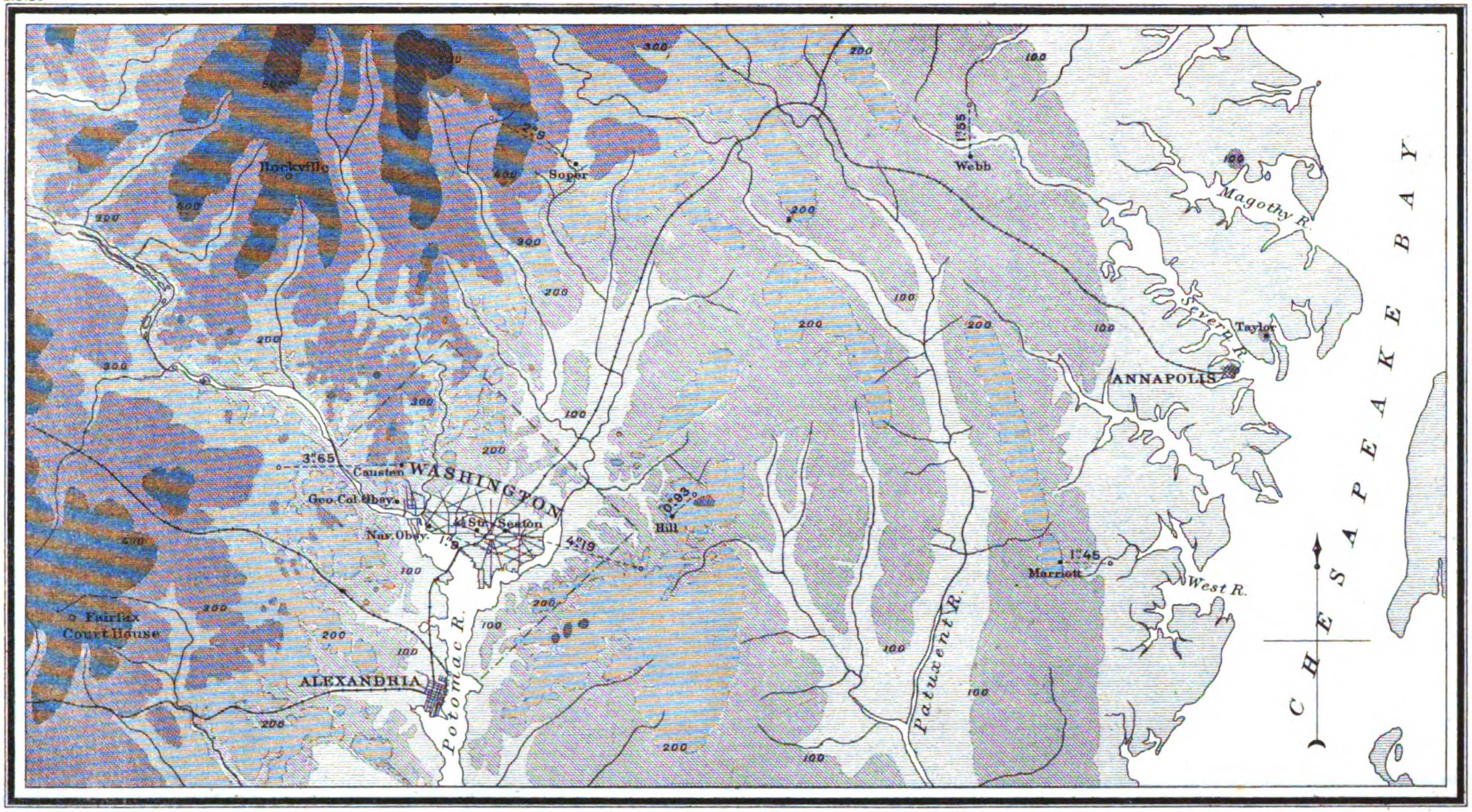
No. 415 PRICE 15 CENTS



Local deflections of the Zenith at some stations near Washington City

To illustrate Appendix No. 7 Coast Survey Report of 1869

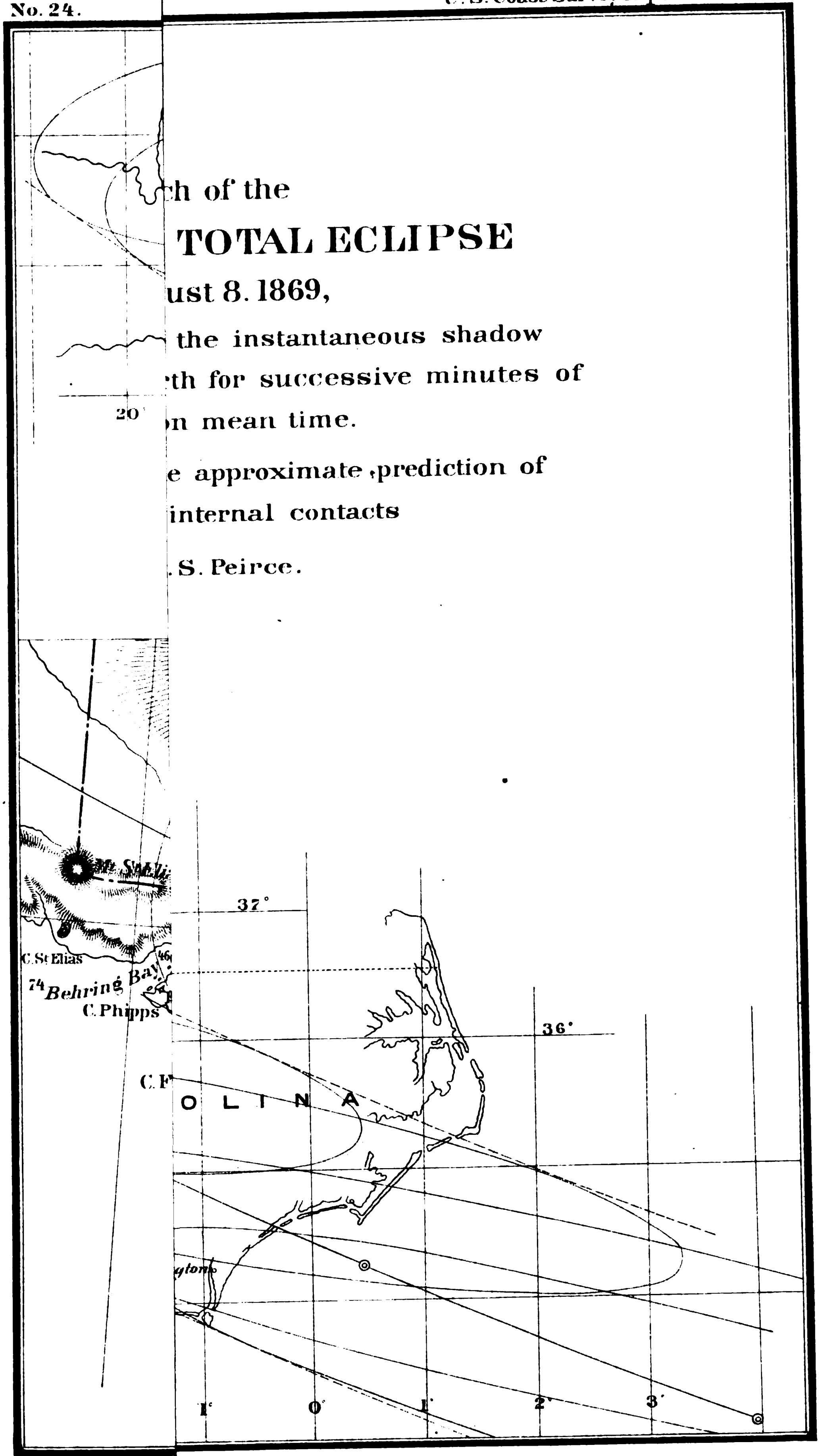
No. 23



• indicates position of astronomical station.
∘ " " " its deflected zenith.

Scale $\frac{1}{400000}$

The areas between each successive 100 feet of elevation are represented by different shadings.



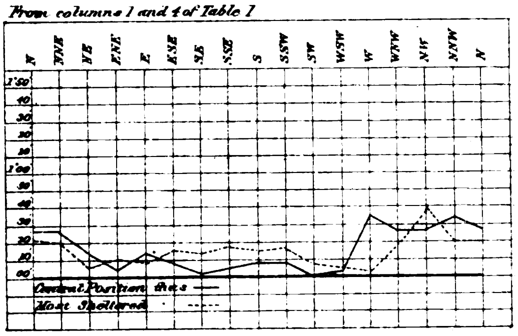
h of the
TOTAL ECLIPSE
ust 8. 1869,
the instantaneous shadow
th for successive minutes of
n mean time.
e approximate prediction of
internal contacts
. S. Peirce.
20
Mt. St. Elias
C. St Elias
74 Behring Bay
C. Phipps
C. F
O L I N A
37°
36°
1
0
1
2
3

HARBORS OF REFUGE COMPARED.

LAND PROFILE.

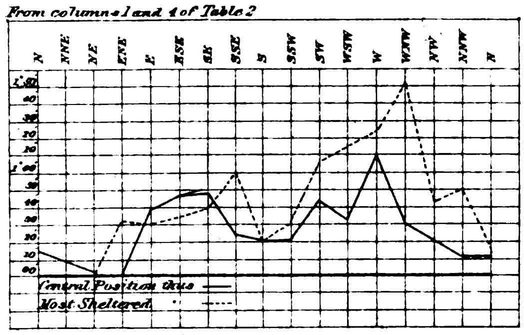
PROVINCETOWN HARBOR.

From columns 1 and 4 of Table 1



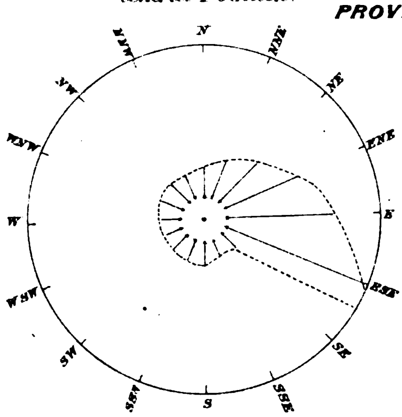
VINEYARD HAVEN.

From columns 1 and 4 of Table 2

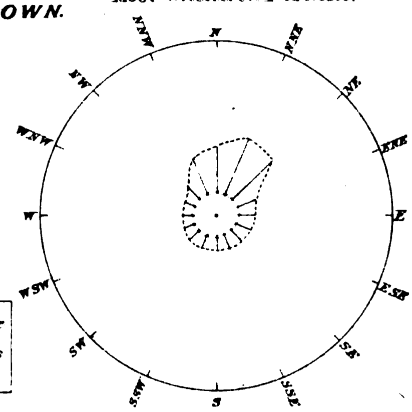


EXPOSURE OF ANCHORAGE AT PROVINCETOWN. MASS.

Central Position.



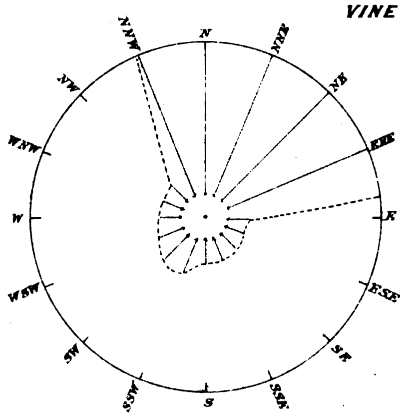
Most Sheltered Position.



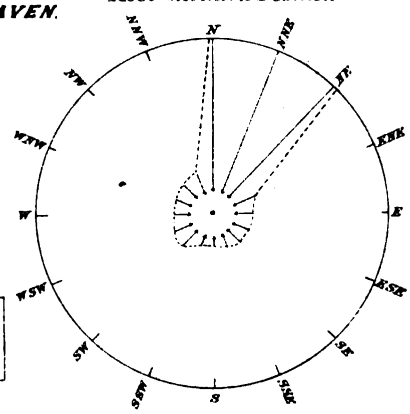
Anchorage 141 Acres

AT VINEYARD HAVEN. MASS.

Central Position.



Most Sheltered Position.

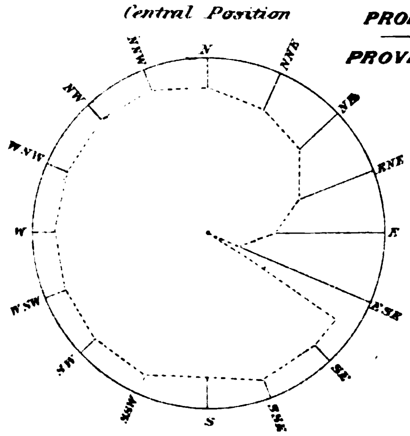


Anchorage 544 Acres

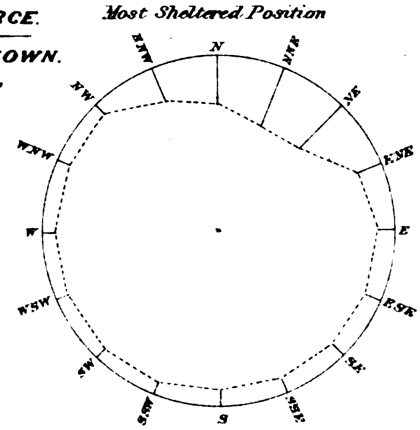
Method of Illustration suggested by

PROF. PEIRCE. AT PROVINCETOWN. MASS.

Central Position



Most Sheltered Position



To accompany the Report of H. Mitchell.